RESOURCE CONSERVATION

GUIDE TO Resource Conservation and Cost Savings Opportunities in the Plastics Processing Sector

Ministry of the Environment

Guide to
Resource Conservation and Cost Savings Opportunities in the Plastics Processing Sector

November 1997

ADVANCE COPY

Prepared for:

Ministry of the Environment

by:

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Mississauga, Ontario

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November, 1997

Dear Reader:

The Ontario Ministry of the Environment (MOE) and the Canadian Plastics Industry Association (CPIA) - Ontario Region are pleased to provide this copy of the Guide to Resource Conservation and Cost Savings Opportunities in the Plastics Processing Sector. The guide was prepared jointly by the ministry and CPIA, with support from the Ontario Ministry of Economic Development, Trade and Tourism and Industry Canada.

This guide identifies and promotes opportunities for conserving energy and water, as well as reducing waste, in the plastics processing sector. By taking advantage of these opportunities, companies can lower their costs while conserving valuable resources.

A wide range of groups have an interest in further refining plastics processing techniques, including facility owners, managers and production supervisors, maintenance staff, employees, suppliers, designers, consultants and industry associations. By combining their own skills and knowledge with the information contained in this guide, these groups can help keep the Ontario plastics processing industry competitive by becoming more efficient and conserving valuable resources.

We hope this guide is useful to you and/or your company or organization. We would be grateful to receive any comments or questions you may have about this publication. A form is enclosed so that you can send comments by fax or by mail.

You may also contact the Canadian Plastics Industry Association (CPIA) - Ontario Region at (416) 323-1883 and the Industry Conservation Branch of the Ministry of the Environment at (416) 327-1439.

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EXECUTIVE SUMMARY

Purpose of Guide

The *Guide to Resource Conservation and Cost Savings Opportunities in the Plastics Processing Sector* was prepared to help plastics manufacturers identify equipment, auxiliary systems and process improvements that will reduce production costs, improve the firms' competitive position, conserve energy, water and other resources and reduce pollution. The guide is intended to be a helpful tool that can be used in conjunction with existing skills and knowledge among stakeholders who share an interest in the plastics processing sector. Individuals and groups interested in this guide could include owners, managers, production supervisors, maintenance staff, employees, suppliers, designers, consultants and industry associations.

This guide looks at five areas of the plastics sector with significant opportunities for improvement. These areas include 1) material conservation, 2) energy savings, 3) water conservation, 4) auxiliary systems and facility equipment savings and 5) emissions reduction.

Raw materials typically constitute 50% - 70% of the manufacturing costs of a plastic processing operation. This guide provides a series of recommendations to reduce raw material waste through improved handling and processing methods. Case studies illustrate reductions in raw material waste and scrap recovery of up to 88%.

This guide discusses electricity and natural gas consumption reduction opportunities available from new technologies, as well as retrofits of existing machinery and auxiliary equipment. Variable speed motors have demonstrated energy savings of up to 40% in some applications.

For processors who do not recirculate cooling water, the guide provides a methodology for evaluating the payback for an appropriate recycling system. In addition to the direct savings from recirculating cooling water, an Ontario processor also saved $43,000 in energy costs per year by installing "free" cooling.

In addition to reductions in process cost, savings can be obtained in the auxiliary systems and facility equipment. A producer of weatherstripping has achieved savings in excess of $40,000 per year by using natural gas powered dryers.

Compliance with environmental regulations and further reduction of emissions are both areas of growing concern. With an investment of less than $10,000, a moulder has saved $13,000 per year by recycling hydraulic oil.

The majority of plastic processes generate relatively few environmental problems. There are however wastes that are generated and by reducing these wastes and emissions, cost savings may be achieved.

The seven generic processes described in this guide are estimated to include more than ninety percent of the plastics processing activity in Ontario. Five thermoplastic processes are discussed;

- Profile extrusion
- Thermoplastic injection moulding
- Flat film or sheet extrusion
- Blown film extrusion
- Blow moulding

Two thermoset processes are also discussed;

- Compression moulding of thermoset plastics
- Foam moulding

In addition to these processes, auxiliary equipment and general plant systems common to most plastics operations are also discussed.

Contents of the Guide
Information provided in this guide is outlined below:

Chapter 1, *Introduction,* outlines the purpose of the guide and the intended target audience and provides process specific checklists to direct the reader to areas of particular interest.

Chapter 2, *Sector profile*, describes the main characteristics of Ontario's plastics processing sector and provides data on the number of plants, major current economic influences, emerging issues, resource requirements, process residuals and relevant legislation.

Chapter 3, *Generic processes, products and product markets,* identifies the targeted generic processes discussed in the guide and provides general information on the significant products and markets for Ontario's plastics processors.

Chapter 4, *Generic process and auxiliary systems descriptions,* provides a narrative description of the processes, major resource inputs and also includes process flow diagrams.

Chapter 5, *Generic improvement opportunities,* describes cost saving opportunities from improved use of raw materials, energy savings, water recirculation and resource conservation opportunities available from process improvements, auxiliary systems and more efficient process equipment. Suggestions are also provided for reducing environmental impacts from operations.

Chapter 6, *New and emerging technologies,* describes technical developments which could have a growing or potentially significant impact on the sector.

Chapter 7, *Benchmarking and performance monitoring,* provides suggestions for calculating baseline efficiency measures to assess improvements and to benchmark the company's performance during specific time periods and in relation to information available from external sources.

Chapter 8, *Other Helpful Information,* provides carefully chosen reference materials that offer further helpful information to the reader.

Appendices to this guide provide summaries of sector specific studies on energy consumption and savings opportunities, sources for case studies, additional detail on Environmental Management Systems and also a summary of the scope of generic plastics manufacturing processes used in Canada.

How to Use This Guide

A detailed Table of Contents is provided in the next section. For readers who wish to proceed directly to specific processes and/or resource conservation improvement opportunities for a specific process or auxiliary system, the next two tables on page iv list starting points for key topics found in Chapters 4 and 5.

Chapter 4 outlines generic process and auxiliary system descriptions. Simplified process diagrams illustrate locations of raw material and other resource inputs as well as pinpointing sources of emissions and effluents.

Chapter 5 outlines generic improvement opportunities. Initiatives are described that have been used successfully by other processors to reduce material, energy and water use and to reduce waste disposal charges and emissions. As well, this chapter will assist a processor to identify opportunities, some of which may be implemented at little or no cost. For other changes, a more detailed analysis is required to demonstrate the costs and benefits and to assign priorities to projects which best meet the company's objectives.

SUMMARY OF STARTING POINTS FOR GENERIC PROCESSES

GENERIC PROCESS	SECTION REFERENCE
Profile Extrusion	4.1
Thermoplastic Injection Moulding	4.2
Flat Film or Sheet Extrusion	4.3
Blown Film Extrusion	4.4
Blow Moulding	4.5
Compression Moulding of Thermoset Plastics	4.6
Foam Moulding	4.7
Auxiliary Systems	4.8

SUMMARY OF STARTING POINTS FOR IMPROVEMENT OPPORTUNITIES

IMPROVEMENT OPPORTUNITY	SECTION REFERENCE
Resin Conservation	5.1.3
Process Energy Reduction	5.2
Water Conservation	5.3
Savings from Efficient Auxiliary Equipment	5.4
Emissions Reduction	5.5
Environmental Management Systems	5.6
Case Studies in Resource Conservation	5.7
New and Emerging Technologies	6

The following tables provide guidance for readers who wish to locate process specific information quickly. These tables also serve as useful checklists for evaluating resource conservation opportunities at any given plastics processing facility.

Profile Extrusion		
Generic Process and Utility Improvement Opportunities		
Process Area	**Opportunity**	**Section Reference**
Material Handling	• Pellet control program • Motors for pneumatic systems	5.1.1 & 5.1.2 5.2.2 & 5.2.3
Drying (Hygroscopic Materials)	• Dryers • Microwave drying • Gas fired dryers	5.4.1 6.5 6.4
Screws and Barrels	• Screws and barrels	5.2.8
Screw Drive	• Motors for drives • Variable speed drives	5.2.2 & 5.2.3 5.2.4
Barrel Heating	• Electrical systems • Barrel heating	5.4.2 5.2.8 & 5.4.5
Barrel Cooling	• Cooling systems • Electric motors for cooling/pumping • Variable speed drives	5.3 5.2.2 & 5.2.3 5.2.4
Regrind Process	• Grinders • Motors	6.6 5.2.2 & 5.2.3
Ventilation	• Air residuals - gases • Air residuals - dust • Motors • Variable speed drives	5.5.2 5.5.3 5.2.2 & 5.2.3 5.2.4
Compressed Air Usage	• Compressed air systems • Motors	5.4.3 5.2.2 & 5.2.3
Vacuum Systems and Pullers	• Motors	5.2.2 & 5.2.3
Bath Cooling	• Cooling systems • Motors • Variable speed drives	5.3 5.2.2 & 5.2.3 5.2.4
Cut-off Equipment	• Motors • Components • Compressed Air	5.2.2 & 5.2.3 5.2.7 5.4.3

Thermoplastic Injection Moulding		
Generic Process and Utility Improvement Opportunities		
Process Area	**Opportunity**	**Section Reference**
Material Handling	• Pellet control program • Motors for pneumatic systems	5.1.1 & 5.1.2 5.2.2 & 5.2.3
Drying (Hygroscopic Mat'ls)	• Dryers • Microwave drying • Gas fired dryers	5.4.1 6.5 6.4
Screws and Barrels	• Screws and barrels	5.2.8
Screw Drive	• Motors for drives • Variable speed drives • Components • Hydraulic motors/systems	5.2.2 & 5.2.3 5.2.4 5.2.7 5.2.5 & 5.2.6
Barrel Heating	• Electrical systems • Barrel heating	5.4.2 5.2.8 & 5.4.5
Barrel Cooling	• Cooling systems • Electric motors for cooling/pumping • Variable speed drives	5.3 5.2.2 & 5.2.3 5.2.4
Regrind Process	• Grinders • Motors	6.6 5.2.2 & 5.2.3
Ventilation	• Air residuals - gases • Air residuals - dust • Motors • Variable speed drives	5.5.2 5.5.3 5.2.2 & 5.2.3 5.2.4
Injection Ram and Mould Opening/Closing Systems	• Hydraulic systems	5.2.5 & 5.2.6
Mould Heating	• Process Insulation	5.4.5
Mould Cooling	• Cooling systems • Electric motors for cooling/pumping • Variable speed drives	5.3 5.2.2 & 5.2.3 5.2.4

Flat Film or Sheet Extrusion		
Generic Process and Utility Improvement Opportunities		
Process Area	**Opportunity**	**Section Reference**
Material Handling	• Pellet control program • Motors for pneumatic systems	5.1.1 & 5.1.2 5.2.2 & 5.2.3
Drying (Hygroscopic Mat'ls)	• Dryers • Microwave drying • Gas fired dryers	5.4.1 6.5 6.4
Screws and Barrels	• Screws and barrels	5.2.8
Screw Drive	• Motors for drives • Variable speed drives	5.2.2 & 5.2.3 5.2.4
Barrel Heating	• Electrical systems • Barrel heating	5.4.2 5.2.8 & 5.4.5
Barrel Cooling	• Cooling systems • Electric motors for cooling/pumping • Variable speed drives	5.3 5.2.2 & 5.2.3 5.2.4
Ventilation	• Air residuals - gases • Air residuals - dust • Motors • Variable speed drives	5.5.2.1 5.5.3 5.2.2 & 5.2.3 5.2.4
Winder	• Motors	5.2.2 & 5.2.3
Chiller Rollers Cooling	• Cooling systems • Electric motors for cooling/pumping • Variable speed drives	5.3 5.2.2 & 5.2.3 5.2.4

Blown Film Extrusion		
Generic Process and Utility Improvement Opportunities		
Process Area	**Opportunity**	**Section Reference**
Material Handling	• Pellet control program • Motors for pneumatic systems	5.1.1 & 5.1.2 5.2.2 & 5.2.3
Drying (Hygroscopic Mat'ls)	• Dryers • Microwave drying • Gas fired dryers	5.4.1 6.5 6.4
Screws and Barrels	• Screws and barrels	5.2.8
Screw Drive	• Motors for drives • Variable speed drives	5.2.2 & 5.2.3 5.2.4
Barrel Heating	• Electrical systems • Barrel heating	5.4.2 5.2.8 & 5.4.5
Barrel Cooling	• Cooling systems • Electric motors for cooling/pumping • Variable speed drives	5.3 5.2.2 & 5.2.3 5.2.4
Ventilation	• Air residuals - gases • Air residuals - dust • Motors • Variable speed drives	5.5.2.1 5.5.3 5.2.2 & 5.2.3 5.2.4
Compressed Air Usage	• Compressed air systems • Motors	5.4.3 5.2.2 & 5.2.3
High Volume Low Pressure Fans	• Motors • Variable speed drives	5.2.2 & 5.2.3 5.2.4
Winder	• Motors	5.2.2 & 5.2.3
Cooling Ring	• Cooling systems • Electric motors for cooling/pumping • Variable speed drives	5.3 5.2.2 & 5.2.3 5.2.4

Blow Moulding		
Generic Process and Utility Improvement Opportunities		
Process Area	**Opportunity**	**Section Reference**
Material Handling	• Pellet control program • Motors for pneumatic systems	5.1.1 & 5.1.2 5.2.2 & 5.2.3
Drying (Hygroscopic Mat'ls)	• Dryers • Microwave drying • Gas fired dryers	5.4.1 6.5 6.4
Screws and Barrels	• Screws and barrels	5.2.8
Screw Drive	• Motors for drives • Variable speed drives	5.2.2 & 5.2.3 5.2.4
Barrel Heating	• Electrical systems • Barrel heating	5.4.2 5.2.8 & 5.4.5
Barrel Cooling	• Cooling systems • Electric motors for cooling/pumping • Variable speed drives	5.3 5.2.2 & 5.2.3 5.2.4
Regrind Process	• Grinders • Motors	6.6 5.2.2 & 5.2.3
Ventilation	• Air residuals - gases • Air residuals - dust • Motors • Variable speed drives	5.5.2.1 5.5.3 5.2.2 & 5.2.3 5.2.4
Compressed Air Usage	• Compressed air systems • Motors	5.4.3 5.2.2 & 5.2.3
Mould and Parison Transport Systems	• Motors for drives • Components • Hydraulic motors/systems	5.2.2 & 5.2.3 5.2.7 5.2.5 & 5.2.6
Mould Clamping System	• Hydraulic system	5.2.5 & 5.2.6
Mould Cooling	• Cooling systems • Electric motors for cooling/pumping • Variable speed drives	5.3 5.2.2 & 5.2.3 5.2.4

Compression Moulding of Thermoset Plastics		
Generic Process and Utility Improvement Opportunities		
Process Area	**Opportunity**	**Section Reference**
Mould Heating	• Process Insulation	5.4.5
Mould Opening/Closing System	• Hydraulic system	5.2.5 & 5.2.6
Compressed Air Usage	• Compressed air systems • Motors	5.4.3 5.2.2 & 5.2.3

Foam Moulding		
Generic Process and Utility Improvement Opportunities		
Agitators	• Motors for drives • Components • Hydraulic motors/systems	5.2.2 & 5.2.3 5.2.7 5.2.5 & 5.2.6
Process Pumps	• Motors for drives • Variable speed drives	5.2.2 & 5.2.3 5.2.4
Process Cooling	• Cooling systems • Electric motors for cooling/pumping • Variable speed drives	5.3 5.2.2 & 5.2.3 5.2.4
Mould Opening/Closing System	• Hydraulic system	5.2.5 & 5.2.6
Material Heating	• Electrical systems	5.4.2 & 5.4.5
Mould Transport Systems	• Motors • Hydraulic motors/systems	5.2.2 & 5.2.3 5.2.7, 5.2.5 & 5.2.6
Compressed Air Usage	• Compressed air systems • Motors	5.4.3 5.2.2 & 5.2.3

Auxiliary Processes		
Generic Process and Utility Improvement Opportunities		
Process Area	**Opportunity**	**Section Reference**
Replacement of Once Through Cooling	• Cooling systems	5.3
Cooling System Motors	• Electric motors for cooling/pumping • Variable speed drives	5.2.2 & 5.2.3 5.2.4
Free Cooling	• Explanation of free cooling	Dia. 4.8 - 1a
Hydraulic Systems	• Cooling systems • Motors • Variable speed drives • Hydraulic components	5.3 5.2.2 & 5.2.3 5.2.4 5.2.7, 5.2.5 & 5.2.6
Thermal Oil Systems	• Cooling systems • Motors • Variable speed drives	5.3 5.2.2 & 5.2.3 5.2.4
Compressed Air Systems	• Cooling systems • Motors • Variable speed drives • Compressed air systems	5.3 5.2.2 & 5.2.3 5.2.4 5.4.3
Pneumatic Raw Material Handling System	• Air residuals - gases • Air residuals - dust • Motors • Variable speed drives • Compressed air systems • Dryers	5.5.2.1 5.5.3 5.2.2 & 5.2.3 5.2.4 5.4.3 5.4.1
Ventilation	• Dryers • Microwave drying • Gas fired dryers	5.4.1 6.5 6.4
General Plant Systems	• Wastewater • Storm water • Replacing Inefficient Equipment • Compressed air systems • Plant lighting • Building heating, cooling & ventilation	5.5.4 & 5.5.8 5.5.9 5.2.2 & 5.2.7 5.4.3 5.4.4 5.4.6

Emissions Reduction Opportunities		
Process Area	**Opportunity**	**Section Reference**
Resin Conservation	• Pellet control program • Material use reduction in processing • Regrind	5.1.3.1 5.1.3.2 5.1.3.3
Air emissions	• Greenhouse gases • Carbon dioxide • Dust	5.5.1 5.5.1 5.5.1
Wastewater and liquid wastes	• Oil interceptors • Floor drains	5.5.2 5.5.2
Solid waste	• Source separation and recycling	5.5.3
Noise	• Noise survey	5.5.4
Stormwater	• Stormwater management plan	5.5.5
Environmental management systems	• ISO 14001	5.6

Follow-up Services Available

The Industry Conservation Branch (ICB) of the Ministry of Environment can provide assistance to companies in developing a resource conservation plan. Utility bill analysis is a service offered to Ontario companies as the first step in conducting a resource assessment of a plant. The analysis provides a quick indication of an individual company's energy consumption patterns and the efficiency of operations. Immediate savings can often be identified in the analysis of gas, electricity, oil and propane, and water consumption patterns. A follow-up plant "walk-through" analysis identifies potential operational savings in energy, water and other process-related resource use in the facilities. Companies can then pursue resource conservation opportunities using their own technical staff or with the assistance of an external consultant. Contact the Industry Conservation Branch at (416) 327-1453 for more information on these services.

Guide to Resource Conservation and Cost Savings Opportunities in the Plastics Processing Sector

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1. INTRODUCTION

The plastics processing sector represents a large and growing sector of the Ontario economy. This sector was selected by the Industry Conservation Branch of the Ontario Ministry of Environment (MOE) for a sector specific assessment to highlight opportunities for energy and water efficiency improvement, resource conservation, and reduction of environmental releases at source.

The *Guide to Resource Conservation and Cost Savings Opportunities in the Plastics Processing Sector* was prepared to help plastics manufacturers to identify equipment, auxiliary systems and process improvements that will reduce production costs, improve the firms' competitive position, conserve energy, water and other resources and reduce pollution. The guide is intended to be a helpful tool that can be used in conjunction with existing skills and knowledge among stakeholders who share an interest in the plastics processing sector.

The primary users of this guide will be the plastics processing executives who make equipment purchases, process improvements and maintenance decisions in a competitive environment. However, the audience for this guide will include all stakeholders in the plastics manufacturing industry. Other readers who will benefit may include owners, managers, production supervisors, maintenance staff, employees, suppliers, designers, consultants and industry associations. For readers who are not familiar with the industry and its technology, Chapter 4, "Generic Process Descriptions," presents simplified process descriptions and generic process diagrams.

An effective resource conservation and pollution prevention program requires a detailed site specific assessment. Priorities consistent with management objectives must be established with a clear understanding of the plant's current performance. In many cases, the level of technical analysis required is beyond the scope of this guide.

The processes described in this guide are estimated to include over ninety percent of the market activity in Ontario. The significant thermoplastic processes that are discussed include;

- Profile extrusion
- Thermoplastic injection moulding
- Flat film or sheet extrusion
- Blown film extrusion
- Blow moulding

The two thermoset processes that are discussed include;

- Compression moulding of thermoset plastics
- Foam moulding

In addition to these processes, auxiliary equipment and general plant systems common to most plastics operations are also discussed. The plastics processing industry uses a broad range of technologies, not all of which are discussed in this guide. A more complete listing of processes may be found in Appendix III, which outlines the scope of generic plastic manufacturing processes currently used in Canada.

2. SECTOR PROFILE: ONTARIO PLASTICS PROCESSING SECTOR OVERVIEW

The sector activities section in this chapter focuses on the nature of Ontario's plastics processing industry. The plastics processing industry is a significant part of a larger plastics manufacturing sector. Ontario based material suppliers manufacture resins from petrochemical and other feedstocks. Ontario also has several world-class manufacturers of processing machinery and is a major producer of tooling for domestic and international plastics processors.

Ontario's share of the total Canadian sales revenue in the plastics processing sector is approximately 63%. This chapter discusses some of the major economic factors which affect Ontario processors' ability to compete in international markets. Trade balances and trends are also examined.

This section also discusses the resource and energy use by the plastics processing industry and provides a context for discussing savings opportunities.

The process residuals section of the sector overview discusses wastes and emissions which may be generated from plastics processing.

A table listing environmental legislation relevant to the Ontario plastics processing sector is provided.

2.1 Sector Activities

The plastics processing sector is characterized by many different processes and applications which use an ever increasing variety of raw materials. In addition to plants devoted to producing custom products for third parties, many Ontario manufacturers have captive plastics processing operations which manufacture finished goods for sale, or components for other end products. This diversity creates difficulty in assembling accurate statistics for the industry. However, it is clear that the sector represents a significant portion of Ontario's industrial activity and continues to experience a growth rate well in excess of the average for all manufacturers.

In 1996, the Ontario plastics processing sector generated about $11.6 billion in shipments and employed over seventy five thousand people in approximately 1,600 companies. The major markets served by the plastics industry are packaging, construction and transportation (automotive). These segments account for 34%, 26%, and 18% respectively of the total resin processed in Ontario.

A brief profile of the plastic products processing sector is outlined as follows using the most up-to-date readily available data.

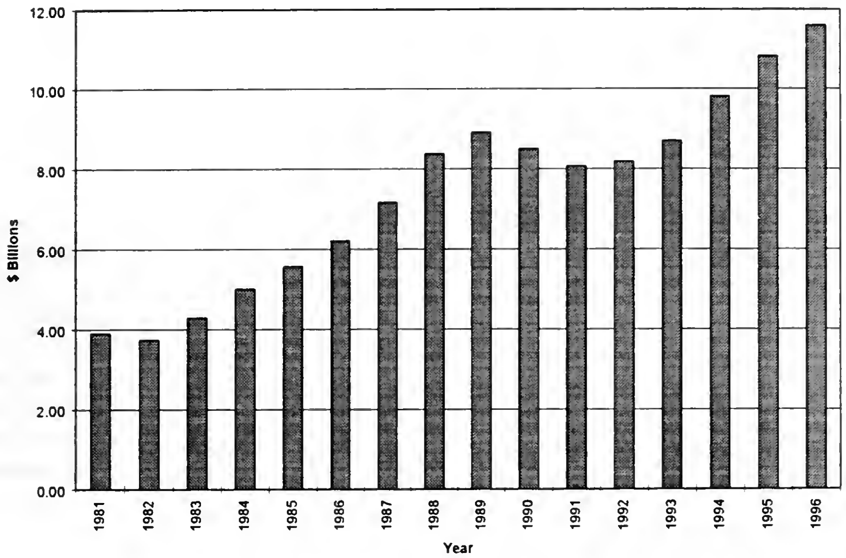
Table 2-1: 1996 Plastics Processing Industry Overview

	ONTARIO	CANADA
Shipments by Processors	$11.6 billion	$18.4 billion
Shipments by Raw Material, Machinery & Mould Suppliers	$5.5 billion	$9 billion
Total Plastics Processing Employment	75,600	120,000
Resin Capacity (metric tonnes)	1.7 million	3.5 million
Annual Growth Rate in Markets	7.2%	7.2%
Average Annual Growth Rate [expressed as the number of times greater than the Average Annual Growth Rate for Canadian manufacturing as a whole (averaged from 1990 - 1996)]	3 times	3 times

Source: Canadian Plastics Industry Association (CPIA)

The introduction of the Free Trade Agreement (FTA) in 1989, the North American Free Trade Agreement (NAFTA) in 1994, a high exchange rate and the onset of a prolonged recession affected Ontario's plastics processing sector. A decline in the value of shipments took place in 1990 and 1991, as shown in Figure 2-1. However, by 1992, the industry resumed a healthy growth pattern which continues to exceed the rate experienced by the overall Canadian manufacturing sector as a whole.

Figure 2-1: Ontario Plastics Industry Shipments



2.2 Industry Structure and Plant Profile

Although some consolidation and rationalization have taken place in the last few years, Ontario's plastics processing industry continues to be characterized by a large number of small and medium-sized enterprises (SMEs).

The average Ontario establishment employs approximately 50 people and has annual sales under $7 million. In recent years, a small but growing number of Ontario-based plastics processors has emerged as significant players in the North American market, each employing several hundred to a thousand plus people. Approximately two-thirds of these larger companies are Canadian owned. Each of these firms has sales volumes in excess of several hundred million dollars and several have international affiliates or subsidiaries.

The structure of the industry showing the flow from raw materials, to products and eventual recycling is shown in Figure 2-2. The custom and proprietary processors produce products which are sold to other manufacturers or marketed directly by the producer. The captive processors incorporate the plastic products manufactured as components into other products.

2.3 Current Economic Status

Historically, many Ontario plastics manufacturers have been at a disadvantage to US producers with larger and more concentrated local markets. The smaller production runs led to higher unit costs. For some bulky products, such as plastic piping, blown bottles or beverage crates, high shipping costs have forced producers to set up operations to serve regional markets. Most of Ontario's plastics processors are located close to their customers in areas of high population density, especially the Greater Toronto Area (GTA) and southern Ontario.

As a result of tariff reductions under the FTA and NAFTA, there has been some rationalization of end-use industries. Certain traditional customers for plastics products have moved out of Ontario to the US and Mexico as a result of the consolidation of production in a US owned firm or the availability of lower Mexican assembly costs for labour intensive products. NAFTA had a modest incremental impact which resulted in some movement out of Ontario of customers for auto-related components and for lower value-added products. These losses have been offset, among other factors, by the general strength of the Canadian automotive assembly sector and the trend to JIT procurement which encourages parts manufacturers to locate near assembly plants.

According to the Canadian Plastics Industry Association (CPIA) the export orientation of the Ontario Plastics Processing industry has been growing quite dramatically. Ontario's trade deficit in plastic products has been in decline since 1993 (Figure 2-3). In 1996, roughly one third of Ontario's trade deficit was with the US. The next largest deficits were with China, Taiwan, Japan and Germany.

Figure 2-2: Position of Processors within the Plastics Industry Structure

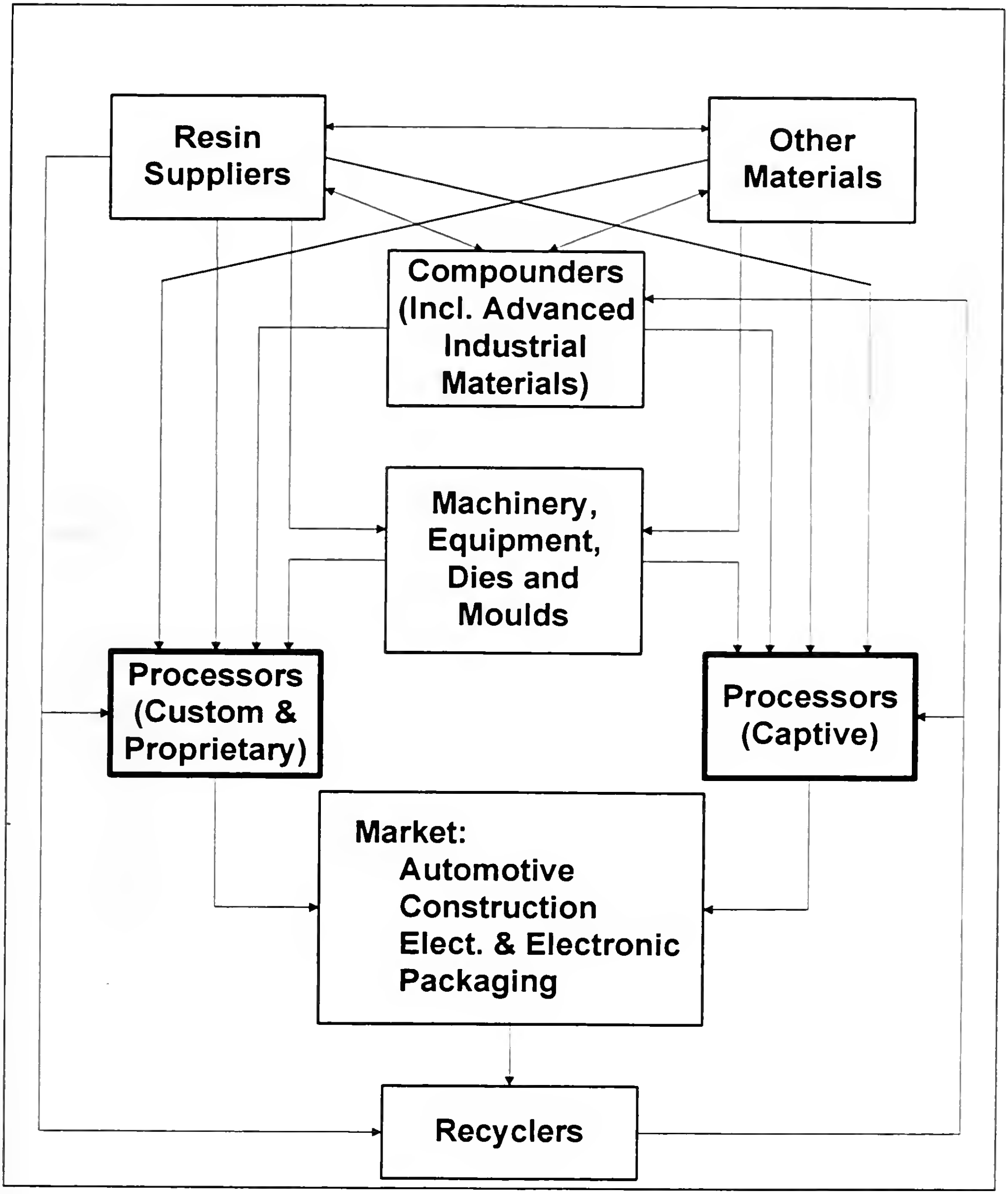
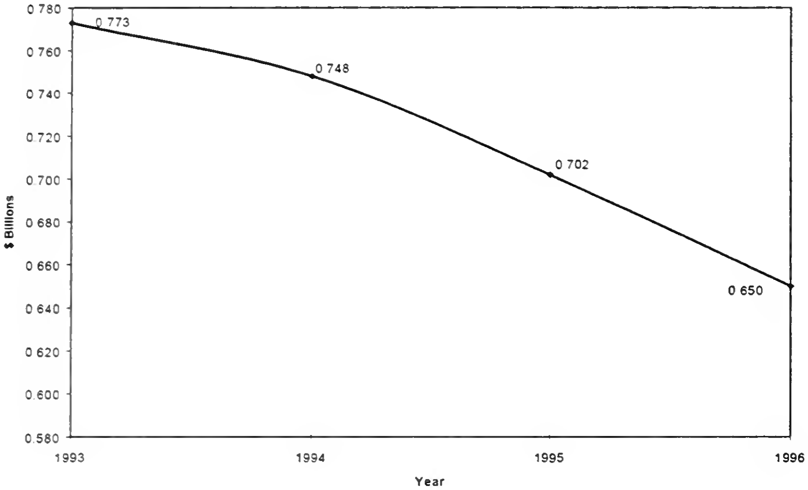


Figure 2-3: Ontario Trade Deficit in Plastic Products



Export sales have risen in recent years (Figure 2-4), as have export sales as a percentage of total shipments (Figure 2-5). These statistics demonstrate that, as a whole, the competitive position of Ontario's plastics processors has improved in recent years.

Figure 2-4: Ontario Plastic Products Exports

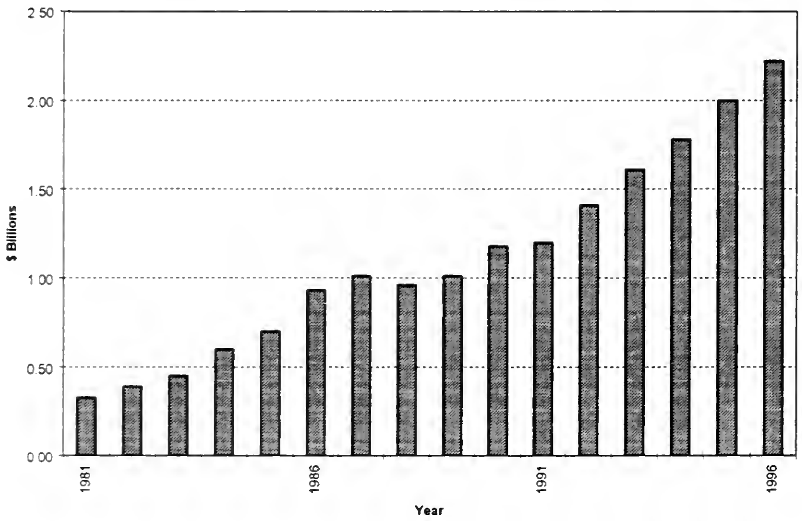
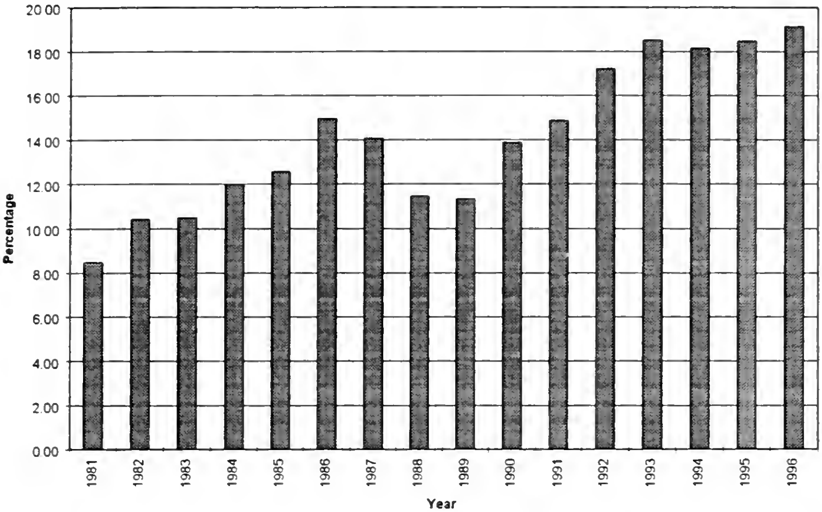


Figure 2-5: Ontario Plastic Products Exports as a Percentage of Shipments



Industry observers contend that Ontario-based plastic processors are well positioned to grow and compete on an international level in the coming years. This view is supported by recent trade data.

A recently published survey of Injection Moulders (*Canadian Plastics Magazine,* January 1997) reflects increased business confidence. Many firms are planning to add capacity, to purchase new equipment and to diversify into new markets. A consideration of the options laid out by this guide will help to ensure that resource efficiencies are built into the industrial infrastructure while investment decisions are being made.

2.4 Emerging Sector Issues

Issues that will be affecting the Ontario plastics industry were examined in a comprehensive manner by the Ministerial Advisory Committee on Plastics (MACP), which issued a report entitled *A Winning Strategy* in 1994. The key concerns outlined in the report are grouped into four categories. The four categories and main corresponding issues are:

1. *Human Resources* - increased industry demand for higher skilled workers
2. *Technology* - firms must be committed to strengthening their technological capabilities to succeed internationally
3. *Environment* - need to meet objectives associated with Reduction, Reuse and Recycling in the Plastics Industry
4. *Trade & Investment* - plastics companies are faced with ongoing pressures to their domestic market from foreign competitors.

The report goes on to relate an overarching objective to reduce Ontario's trade deficit in plastics by approximately $400 million by 1999, through meeting these challenges.

2.5 Resource Utilization

The significant categories of resource usage by the plastics processing sector are discussed below. The use of raw materials, usually the single largest cost factor in a plastics processing operation, is often difficult to track and to manage effectively. Overall energy, water and solid waste disposal costs are readily identifiable from utility and waste management bills. However many plants have little detailed knowledge of associated unit costs by specific machines or processes.

2.5.1 Materials

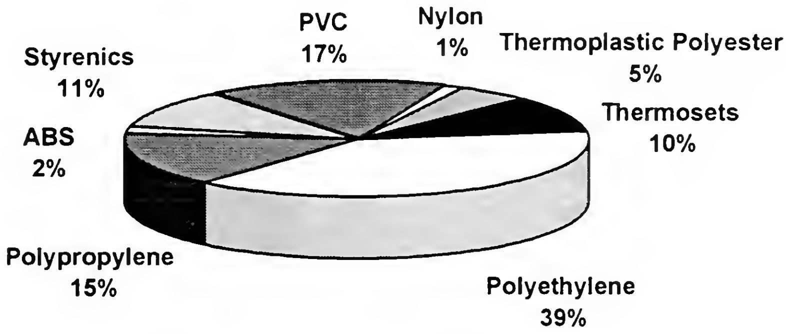
2.5.1.1 Resins

For most manufacturers in this sector, raw materials are the single largest operating cost. In some operations with high throughputs, such as profile extrusion, it is not uncommon for material purchases to exceed 70% of manufacturing expense. Typically, direct labour constitutes 5% - 15% of the expense, while total energy costs are often less than 5%.

Raw materials include resins, UV stabilizers, pigments, lubricants plus other processing aids and additives. This guide focuses primarily on firms which receive thermoplastic resins in pellet form, and does not specifically address operations which compound raw materials. Pellets are routinely shipped in containers ranging from 25 kg bags to 500 kg gaylords, to even larger truck or railcar shipments for high volume producers. Improvements in the handling, processing and recycling of raw materials represents a significant savings opportunity in this sector.

Numerous types of resins are used. Material suppliers constantly increase the range of options available by developing new materials targeted at specific applications. The estimated consumption of resins by major type in North America is provided in Figure 2-6.

Figure 2-6: Estimated North American Consumption of Major Plastic Resins, 1996



* Sources: C.P.I.A.
S.P.I. Committee on Resin Statistics as Compiled by Association Services Group, LLC

2.5.1.2 Other Supplies

Plastics processing facilities use a wide range of plant supplies related to equipment and plant maintenance. Other supply categories related to specific processes and secondary operations are also utilized.

Typical supply categories include:

1) Hydraulic oil-
   Hydraulic oil is used to power process machinery. While the oil does not typically require frequent replacement, losses through leaks and hose breakages may occur.
2) Tool room supplies-
   Tool room supplies include cutting oils, solvents and greases.
3) Processing supplies-
   Some processors add pigments or dyes, and some moulding operations also use mould releases.
4) Plant cleaning supplies-
   Plant cleaning supplies include soaps, detergents and absorbent materials for cleaning up oil spills.
5) Packaging and distribution materials-
   Packaging for incoming materials typically includes bags, gaylords and pallets. Shipments of finished goods may be made in any or all of the following forms; cartons, plastic bags and/or wooden crates.

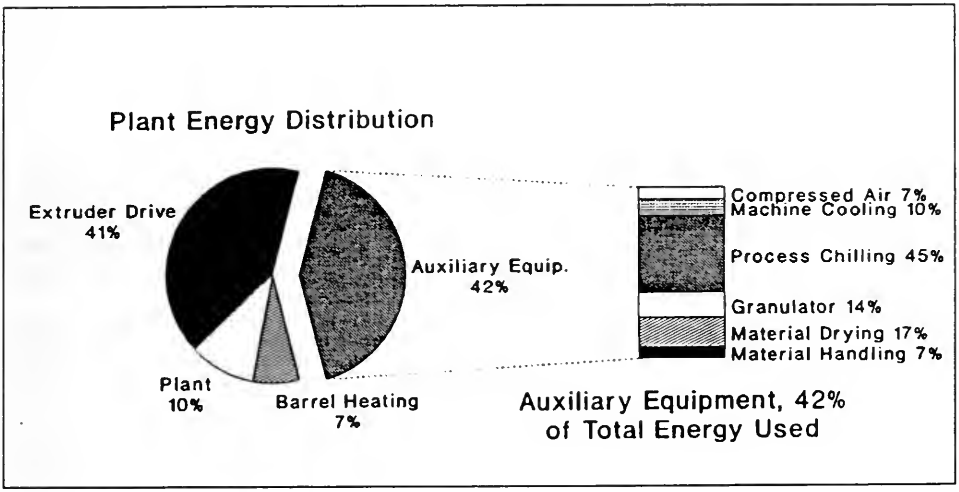
2.5.2 Energy

Detailed estimates of the distribution of energy demand for typical extrusion, injection moulding, blow moulding and blown film plants were developed in 1993 for Energy Mines and Resources, Canada by Power Smart Inc. of Vancouver. This data is summarized in Figure 2-7 for four generic processes; 1) extrusion, 2) injection moulding, 3) blow moulding and 4) blown film.

The estimates illustrate the relative importance of energy demand by the processes and auxiliary equipment as a proportion of the total facility demand. Furthermore, details of the total process demand are provided to assist manufacturers to identify priority areas for energy reduction projects.

Figure 2-7: Estimate of Plant Energy Distribution From Selected Plastic Processes

Extrusion



Injection Moulding

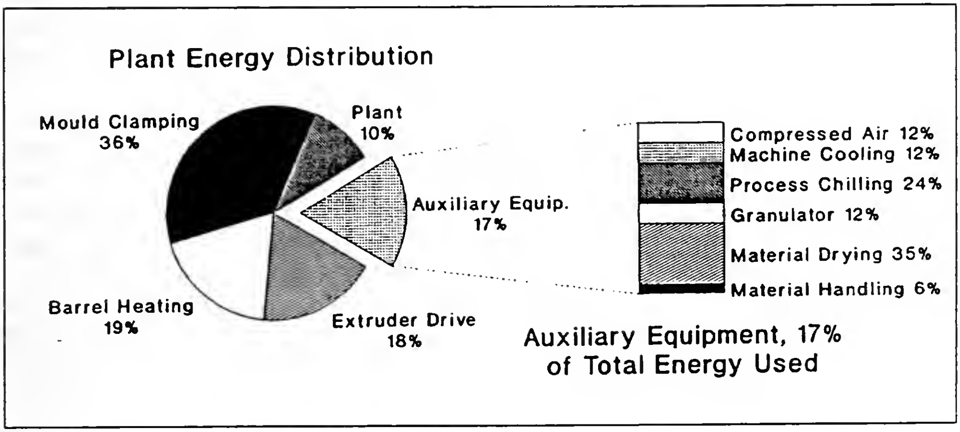
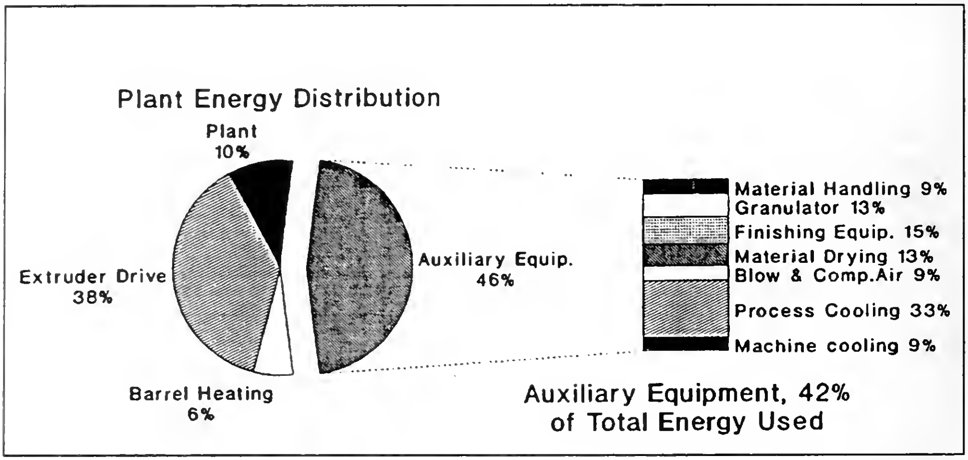
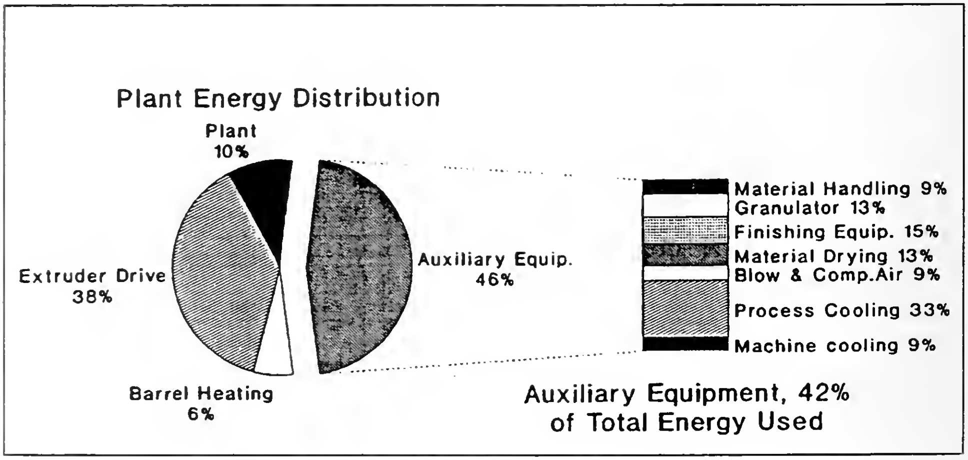


Figure 2.7: Estimate of Plant Energy Distribution From Selected Plastics Processes (Continued)

Blow Moulding



Blown Film



2.5.2.1 Electricity

Electricity is the main source of energy used by plastics processors. The main uses of electricity include such applications as providing heat to extruder barrels through resistance heaters and energizing extruder drives. Electricity is also used indirectly by providing the power source for hydraulic, chilling, thermal oil heating and compressed air systems. Air conditioning, ventilation and lighting for the facilities are yet other uses of electricity. Electrical costs account for approximately 2% to 3% of the cost of production.

2.5.2.2 Natural Gas

Natural gas is used primarily for water and facilities heating. Other applications which can use natural gas include rotational moulding, pellet dryers and internal combustion engines which can in turn power air compressors, hydraulic systems or electrical generators. Natural gas costs account for approximately 1% of the cost of production.

2.5.3 Water

Water is used for a variety of applications such as a cooling medium for profile extrusions and process machinery components such as moulds and extruder barrels. Water is also used for cooling auxiliary equipment such as hydraulic and compressed air systems. Water usage varies widely by plant and by process.

Some smaller processors use line water in a 'once through' application, discharging to sanitary and/or storm sewers. Larger processors, sometimes require significant volumes of cooling water and as well need to control water temperature. In such cases, closed loop water cooling systems are preferred. Water can be recirculated and cooled using portable or permanent chillers or cooling towers.

Latest available estimates from Environment Canada (1991) indicate that 87% of the water used by Ontario plastics processors is currently being recycled. This further indicates that most processors have recognized it is cost effective to install recycling systems for process cooling water. In addition to the resource conservation and cost savings benefits, the ability to control water temperature allows processors to improve product quality and throughput efficiency.

2.6 Process Residuals

Plastic processors generate various types of wastes and releases to the environment which in many cases can be reduced. Plastic materials, when processed under conditions specified by the manufacturers, are relatively stable and do not present a significant risk to humans or the environment. Cost savings may be achieved however by reducing waste and emissions, especially by improving the management of raw material losses due to inefficiencies.

2.6.1 Air Residuals - Gases and Dust

Greenhouse gas emissions (i.e. principally CO_2 gas) can be reduced through ongoing improvements in energy efficiency at any given plastic processing facility. Although small (i.e. 0.25%) in relation to discharges from other manufacturing activities in Canada, plastic processors generate and discharge approximately 243,000 tonnes of CO_2 annually into the atmosphere. Ongoing improvements to energy efficiency measures are encouraged to minimize energy consumption per unit of product produced, thereby minimizing greenhouse gas emissions.

The Voluntary Challenge and Registry Program (VCR) is a federal-provincial initiative to support the National Action Program on Climate Change (NAPCC). The VCR program encourages the development and implementation of voluntary action plans to improve energy efficiency and therefore minimize CO_2 emissions. Further background and helpful information on practical measures to improve energy efficiency can be found in Chapter 8 in various publications that have been prepared by the Canadian Industry Program for Energy Conservation (CIPEC) and Natural Resources Canada (NRCan).

Some plastics processing emits volatile organic compounds (VOCs) which contribute to the generation of ground-level ozone, a major component of smog. The Ontario Ministry of Environment is working with the Canadian Plastics Industry Association (CPIA) and plastics processors to investigate practical ways in which VOC emissions can be reduced. This industrial sector initiative is one of many that is contributing to the development of the Ontario Smog Reduction Plan. A comprehensive review of VOC reduction opportunities will emerge with the completion of a plastics processor VOC reduction plan as early as 1998.

Sources of VOCs from plastics processors arise predominantly from the use of blowing agents and the degradation and evaporation of polymers and additives. Mould release agents and cleaning/maintenance chemicals also contribute to VOC emissions. Although small (i.e. 0.7%), in relation to emissions from other sources in Ontario it is estimated that plastic processors generate and discharge approximately 6,000 tonnes of VOCs annually into the atmosphere.

Four generic processes account for approximately 60% of the plastics processing sector VOC emissions; 1) expanded polystyrene foam, 2) extruded polyethylene foam, 3) polyvinyl chloride and 4) reinforced plastic and composite products made from thermoset polyester resins. A guideline was published by the Canadian Council of Ministers of the Environment (CCME) in July, 1977 to provide guidance on reducing VOC emissions from plastics processing facilities. The guideline includes performance standards for each of the four targeted processes and includes best management practices which address topics such as raw materials handling, equipment maintenance and operation, management systems and operating procedures.

VOCs emitted from polymer processing are difficult to collect and remove from exhaust air primarily because of the wide variety of chemicals involved such as solvents, polymer degradation products, blowing agents and additive compounds. In addition, many plants operate on a less than three shift, seven days a week basis, which produces further variability in emission rates. For these reasons, the efficiency and cost effectiveness of control devices is poor in the plastics processing sector. However, there are known opportunities for VOC reduction discussed further in Section 5.5.1.

Some plastics processing operations are also known to emit airborne dust particles. Material handling, blending and grinding operations have the potential to generate dust. High levels of dust may create an explosion hazard. Efforts to minimize dust are also encouraged to further reduce employees' exposure to respiratory risk associated with exposure to airborne particles.

2.6.2 *Wastewater and liquid wastes*

Non-contact cooling water may be used for machinery, mould or auxiliary equipment cooling prior to sanitary sewer system discharge. Potential contaminants include particulates such as pellets, hydraulic or lubricating oils and solvents.

Liquid wastes which require special handling commonly generated by the plastics processing industry include used hydraulic oils, spent solvents and other chemicals.

2.6.3 *Solid waste*

The solid waste stream from plastics processing operations typically includes packaging materials such as bags, gaylords and skids, purgings from machine start-ups, degraded material and unsalvageable scrap. Pellets which have been spilled and raw materials which have been contaminated by mixing or by foreign matter may also become solid waste destined for disposal.

Other wastes not specifically related to the process include office waste, waste paper, corrugated packaging, cafeteria/lunch room food wastes, bottles and cans and landscaping wastes.

2.6.4 *Noise*

Hydraulic pumps, scrap grinders, sonic welders, material handling and conveying equipment are all considered to be common sources of objectionable noise. Excessive noise levels can result in unpleasant working conditions. It may be necessary to control noise levels to prevent exceeedances of the Occupational Health and Safety Regulation limits.

Plant noise which affects neighbouring residential, commercial or industrial operations is regulated by municipal noise control by-laws. Noise sources which may exceed limits and give rise to neighbourhood complaints can include material handling techniques such as the emptying of tank trucks or rail cars.

2.7 Environmental Legislation - Acts and Regulations

Many responsible processors seek to achieve environmental performance that would exceed compliance with environmental legislation. A variety of environmental legislation is of interest and could pertain directly to the plastics processing sector. The legislation is intended to protect the environment from all potential discharges to the air, water and land. A summary of the relevant environmental legislation in Ontario including Acts and regulations is outlined in Table 2-2.

Table 2-2: Summary of Environmental Legislation Relevant to the Ontario Plastics Processing Sector

TOPIC		LEGISLATION (ACTS AND REGULATIONS)	JURISDICTION	ADMINISTERING AGENCY	PURPOSE
All Potential Discharges		Environmental Protection Act (EPA) Certificate of Approval	Provincial	MOEE	Control of discharges to the environment
Waste Management, General		EPA Regulation 347	Provincial	MOEE	Control of waste management systems including hazardous and industrial wastes
3Rs		EPA Regulation 347	Provincial	MOEE	Exemption of recyclable materials from EPA
		EPA Regulation 101/94	Provincial	MOEE	Requirement for municipal residential recycling programs Exemption of recycling facilities from approval procedures
		Regulation 102/94	Provincial	MOEE	ICI waste auditing and reduction
		Regulation 103/94	Provincial	MOEE	ICI source separation
		Regulation 104/94	Provincial	MOEE	Packaging audits and reduction
Air	Particulates	EPA Regulation 346	Provincial	MOEE	Control of emissions
	Odour		Provincial	MOEE	Control of odours
	Ozone depleting substances	EPA Regulation 356	Provincial	MOEE	Restricts the use of ozone depleting substances
Effluent	Direct Discharge	Fisheries Act	Federal	MOEE	Control of discharges to receiving bodies of water
		Ontario Water Resources Act	Provincial	MOEE	Control of discharges to receiving bodies of water
		Environmental Protection Act	Provincial	MOEE	Control of discharges to receiving bodies of water
	Sewer Discharge	EPA Regulation 358	Provincial	MOEE	Control of Sewage Systems
		Municipal Act	Provincial	Municipality	By-Laws to control municipal sanitary sewer discharges

3. GENERIC PROCESSES, PRODUCTS AND PRODUCT MARKETS

Plastics manufacturing processes covered by this guide include the significant, high volume methods for processing thermoplastic materials. Two of the major thermoset processes are also discussed. Industry estimates suggest that the processes listed below capture approximately 90% of the sector activity. Descriptions and illustrations of these generic processes can be found in Chapter 4.

Manufacturing operations will benefit from a review of the material presented in this guide. In addition to resource conservation opportunities for each of the primary processes listed, all plants in the sector utilize energy for plant space heating and cooling, material handling, secondary operations and transportation.

3.1 Generic Processes and Typical Products

Plastics manufacturing processes are versatile and capable of producing a wide variety of end products from a range of thermoplastic and thermoset plastic materials. The products listed along with each production process are a small sample of the applications commonly found.

Six generic thermoplastic processes constituting the majority of production include;

Profile extrusion
- Typical products: pipe, siding, automotive trim.

Injection moulding
- Typical products: containers for retail dairy products, CD cases, pipe fittings.

Sheet extrusion
- Typical products: swimming pool liners.

Injection blow moulding
- Typical products: soft drink bottles, jars.

Blown film extrusion
- Typical products: garbage bags, shopping bags.

Extrusion blow moulding
- Typical products: detergent and lubricant bottles.

Two significant non-thermoplastic processes are also discussed;

Compression moulding of thermoset plastics
- Typical products: automotive panel components, truck air deflectors.

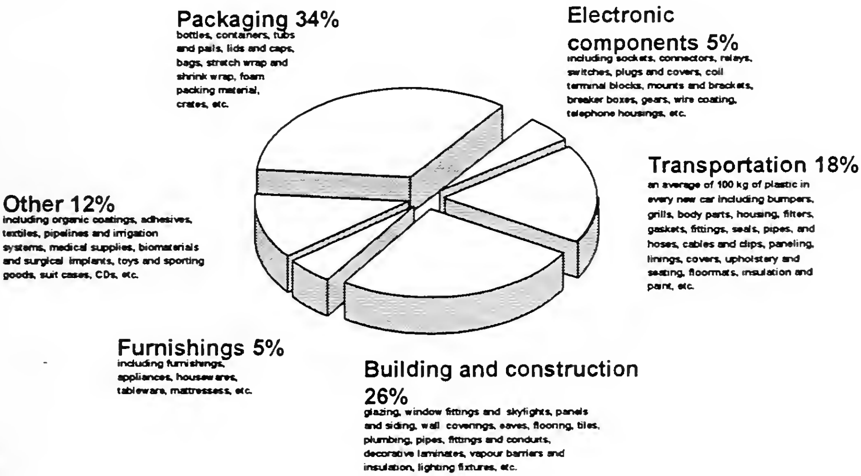
Urethane foam moulding
- Typical products: automotive seat cushions, impact absorbing dashboard components.

There are many other plastics manufacturing processes that are not discussed in this guide. These include such processes as reaction injection moulding, rotational moulding, casting, thermoforming, vacuum forming, pultrusion, hand lay-up and others. In addition, manufacturers perform many types of finishing and secondary operations which are also beyond the scope of this guide. A more comprehensive listing of the generic processes used in Canada are itemized in Appendix III.

3.2 Use of Plastic Products in Various Market Segments

A breakdown of Canadian plastics usage by various end markets and product types are presented in Figure 3-1. This illustration outlines the broad range of product applications and also the significance of plastics processing to Ontario's economy.

Figure 3-1: PLASTIC PRODUCTS AND ASSOCIATED MARKETS



4. GENERIC PROCESS AND AUXILIARY SYSTEMS DESCRIPTIONS

The purpose of highlighting commonly used generic processes is to pinpoint where opportunities may exist to minimize resource consumption and to reduce process discharges. Illustrations of generic processes together with process descriptions are provided. The process diagrams identify resource inputs and sources of effluents. Both the descriptions and diagrams are highly simplified and are intended to serve as an introduction to the technology for readers who are not familiar with the industry.

Several of the processes described below may also be enhanced by feeding more than one material type, colour or grade into the process to manufacture products with layers of dissimilar materials. This enables the manufacturer to obtain improved technical, aesthetic or cost benefits from a single process. In addition, robotics play an increasingly important role in enhancing repeatability in processes, as well as in reducing cost and the risk of accidents. Enhancements such as these are ignored for the sake of simplicity in the process descriptions that are outlined in the text.

Illustrations of auxiliary systems are also provided. Examples of some of the systems illustrated include a closed loop free cooling water system, a compressed air system and a pneumatic raw material handling system. Resource consumption areas and emission points are pinpointed in each of the generic auxiliary systems described.

Readers already familiar with generic processes, process technology and auxiliary systems may proceed directly to Chapter 5, ***Generic Improvement Opportunities.***

4.1 Profile Extrusion

Single screw extrusion is the most commonly used technology for profile extrusion. A thermoplastic raw material, typically in pellet form, is fed from a hopper into a barrel which houses a rotating screw. A small laboratory sized extruder may have a screw diameter of 10 mm, while screws for high-volume extruders may have diameters in excess of 300 mm. The screw is typically driven by a variable speed electric motor which may be coupled to a single or multi-speed gear box.

The screw system performs several functions:

- It conveys material from the hopper to a die located at the opposite end of the barrel.
- The screw plasticizes and pressurizes the material. Heat is generated by a combination of internal heating due to shear and heater bands located outside the barrel. The barrel may be vented to allow gases and water vapour to escape. Venting requires a multiple stage screw, with a decompression zone between the compression stages.

- The screw may be used to blend in colorants and other additives.

- The control of melt temperature, homogeneity and pressure are all critical factors. Thermocouples are used to sense temperature along the barrel and to control the amperage to the heater bands. To prevent excessive shear heat from degrading the material, some barrel zones may be water or air cooled.

The plasticized material is forced through a die to form the desired shape. After passing through the die, the partially solidified extrudate may be further formed by callipers or vacuum sizers to achieve the final desired configuration and to maintain required tolerances. The extrudate is then water or air cooled. When the material has solidified sufficiently to resist damage from handling, a puller system is used to maintain a constant tension on the extrudate. Beyond the puller, a travelling saw or shearing mechanism is used to cut the product into desired lengths for shipment or further processing.

Twin extruders, with two parallel screws, are capable of high output with low shear and are typically used for large volume processing of heat-sensitive materials. Typical applications include siding and pipe produced from non-pelletized (powder) materials. Co-extrusion, the use of more than one extruder to feed a single die, is common.

Most custom operations use various sizes of general purpose extruders. However, significant productivity, quality and energy efficiencies may be achieved by a using a machine matched to a specific job. For a specific material and throughput, it is important to select the appropriate screw diameter, length to diameter (L/D) ratio and operating conditions.

A wide variety of thermoplastic materials may be processed by extrusion. The largest volume material is PVC, which is used for construction vinyl siding, sewer pipe and window lineals. ABS is used for refrigerator trim, drain pipes and furniture components.

Resource Consumption and Emissions in the Profile Extrusion Process

The major energy requirement for this process is the electricity to drive the extruder screw motor. Some electrical energy is used to drive puller motors and cut-off saws. In other cases, the cut-off equipment may be operated by compressed air.

Significant amounts of water may be used to cool the lineals. This water is often recirculated. Water vapour and other gaseous emissions are released into the atmosphere from barrel vents, the feeder throat and the nozzle.

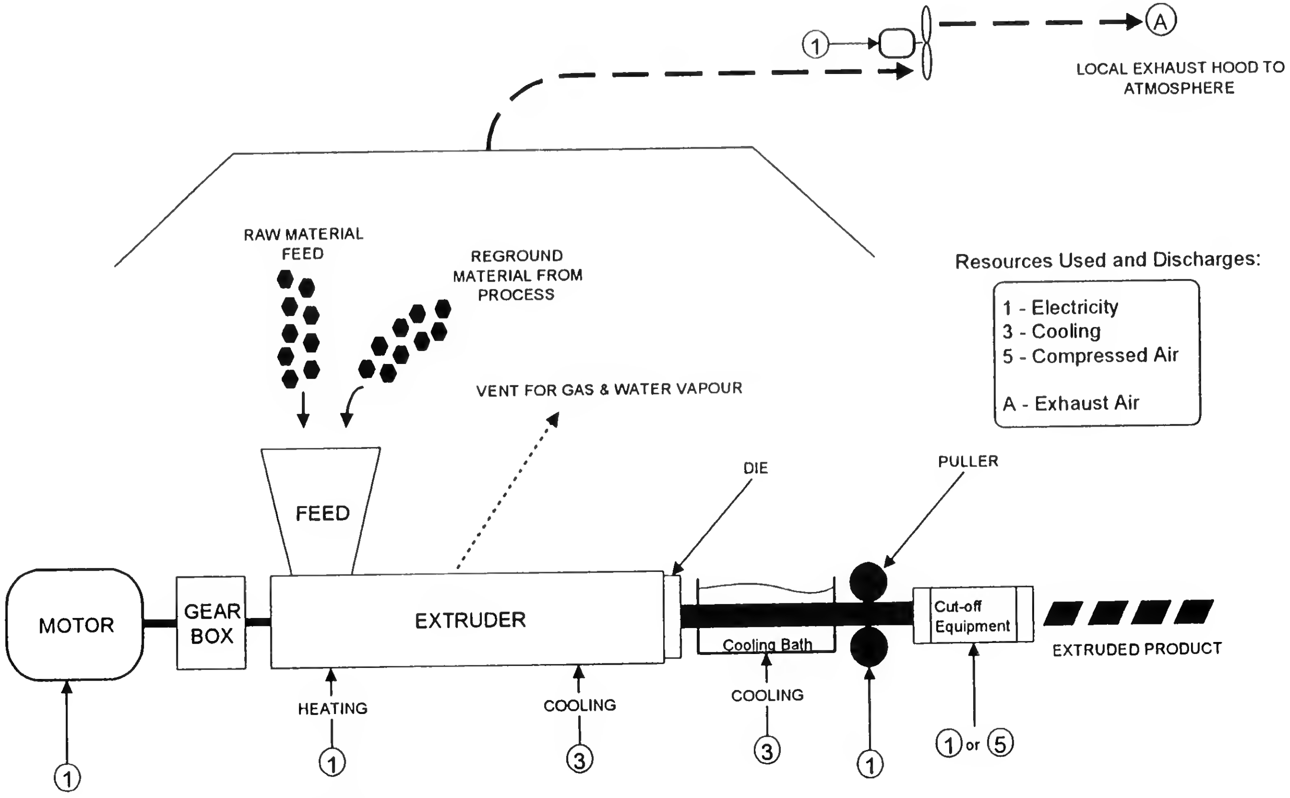


Figure 4-1: Resource Consumption and Emission Points in the Profile Extrusion Process

4.2 Thermoplastic Injection Moulding

Thermoplastic injection moulding is a versatile process used to produce a wide variety of end products. With proper tool design and material selection, injection moulded parts can provide a broad range of physical properties, decorative features and resistance to chemical attack and ageing. When required, metal inserts may be used in injection moulded parts to provide additional strength.

Injection moulding machines are commonly classified by clamp tonnage; the force required to resist the pressure exerted by the material injected into the mould during the injection process. The pressures are frequently high, 20-30,000 PSI. As a result, clamp tonnages normally range from 20 tonnes for a small machine to 6000 tonnes or more for a large press.

The plasticizing of the material is similar to the process described under the Thermoplastic Extrusion process description. The major difference is that in the injection moulding process, the screw retracts while it is rotating and a pre-determined amount of plasticized material accumulates in front of the screw. The screw stops rotating at this point and the screw assembly moves forward to force the material through a nozzle into a mould under high pressure.

Cycle times vary with materials used, wall thickness of the parts and tool technology. Thin walled containers typically have a cycle time of a few seconds. Large parts with heavy sections will take several minutes to solidify before being removed from the mould.

For parts which require trimming, 100% inspection or secondary operations, an operator manually removes the parts from the mould. Alternatively, the parts may be allowed to fall into a container, or robots (sprue pickers) may be used to remove the sprues and/or parts from the mould. In more sophisticated applications, robots are used to package the parts or to transfer them to a secondary operations station.

Various options exist for feeding the material into the mould cavities. The conventional method is to feed material through a sprue and a runner system into one or more mould cavities. After the part has solidified, the mould opens and the parts may be trimmed from the runner system. In most applications, the sprues and runners are reground and fed back into the process.

Various levels of sophistication in tool technology exist to reduce the labour and energy required to trim parts after moulding:

Tunnel or submarine gates are used to separate the part from the runner system during the mould opening sequence.

The effort to separate and re-grind runners may be totally eliminated by using a hot runner system. Heaters built into the mould keep material in the runners in a molten state until the next shot. Although hot runner tooling is more costly, the technology is commonly used for high volume small parts, especially when heat sensitive materials are used. With conventional tooling, the runner to part weight ratio is typically quite high, and materials may become degraded by passing through the heating cycle several times.

Injection moulding is used to process a broad range of materials. Commodity resins, such as polyethylene, are found in toys and polystyrene is used for rigid packaging.

When the end use requires physical or chemical properties which are not available in commodity grades, engineered plastics are used. Nylon, for example, is frequently used in applications which require toughness and lubricity. Some ABS parts, such as faucet handles and automotive trim, are electroplated for decorative and functional applications.

Resource Consumption and Emissions in the Injection Moulding Process
The major energy requirement for this process is the electricity to power the hydraulic systems. The majority of the energy is used to plasticize the material, with lesser amounts required for injection and to transport the moulds.

The moulds are usually water cooled. This water is typically recirculated.

Water vapour and other gaseous emissions are released into the atmosphere from barrel vents, the feeder throat and the nozzle. Mould releases, if used, will also contribute to air emissions. Cooling water is typically recirculated. Leaks from the hydraulic systems may contaminate plant wastewater.

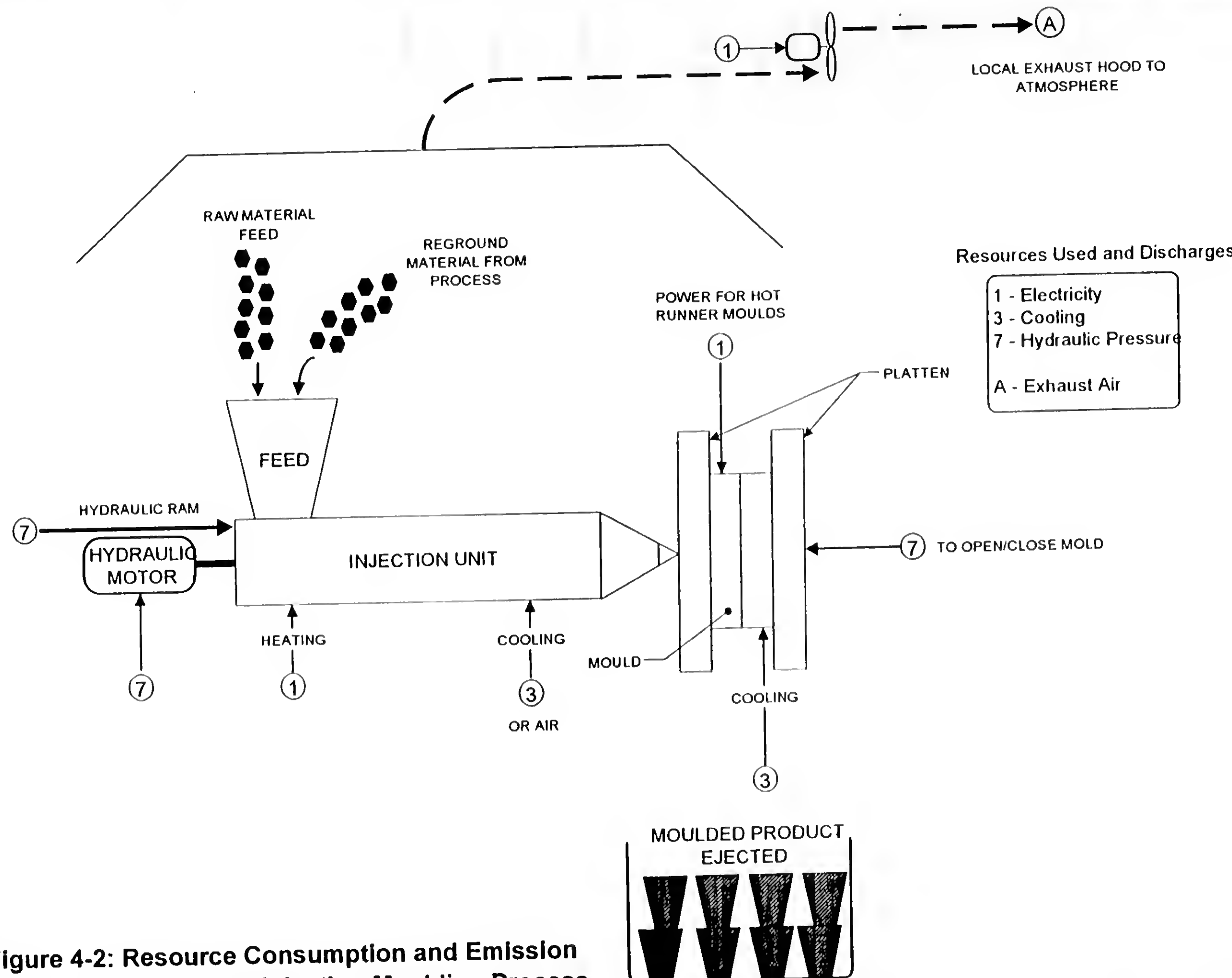


Figure 4-2: Resource Consumption and Emission Points in the Injection Moulding Process

4.3 Flat film or Sheet Extrusion

In this process a slot die, often three to four meters wide, is mounted on an extruder to produce a film. This film is typically fed vertically into a cooling bath and is passed over chilled rolls. The highly polished rolls produce a smooth flat film surface which has excellent clarity. Film thickness is partially a function of the cooling rate. Accurate temperature control of the rolls and cooling baths is important.

The roll mechanism is run at a speed which stretches the film, while reducing its thickness. This process produces a film which has superior physical properties in the direction of the stretch, and lower properties across the film. Biaxially oriented film with good strength in all directions may be obtained by stretching the extruded film both longitudinally and transversely.

Sheet may be produced with a wide range of thicknesses, from thin film for packaging applications to heavier gauges used by whirlpool tub manufacturers. Sheet may be co-extruded from more than one type of material and may be supplied with embossed surfaces.

A wide range of polymers may be processed by sheet extrusion; polyethylene, polypropylene and polystyrene are commonly used.

Resource Consumption and Emissions in the Flat Film or Sheet Extrusion Process

The major energy requirement for this process is the electricity to drive the extruder screw motor. Some electrical energy is used to drive rolls and winder motors.

Significant amounts of water may be used for the chill rolls and cooling baths. This water is often recirculated.

Water vapour and other gaseous emissions are released into the atmosphere from barrel vents, the feeder throat and the die area.

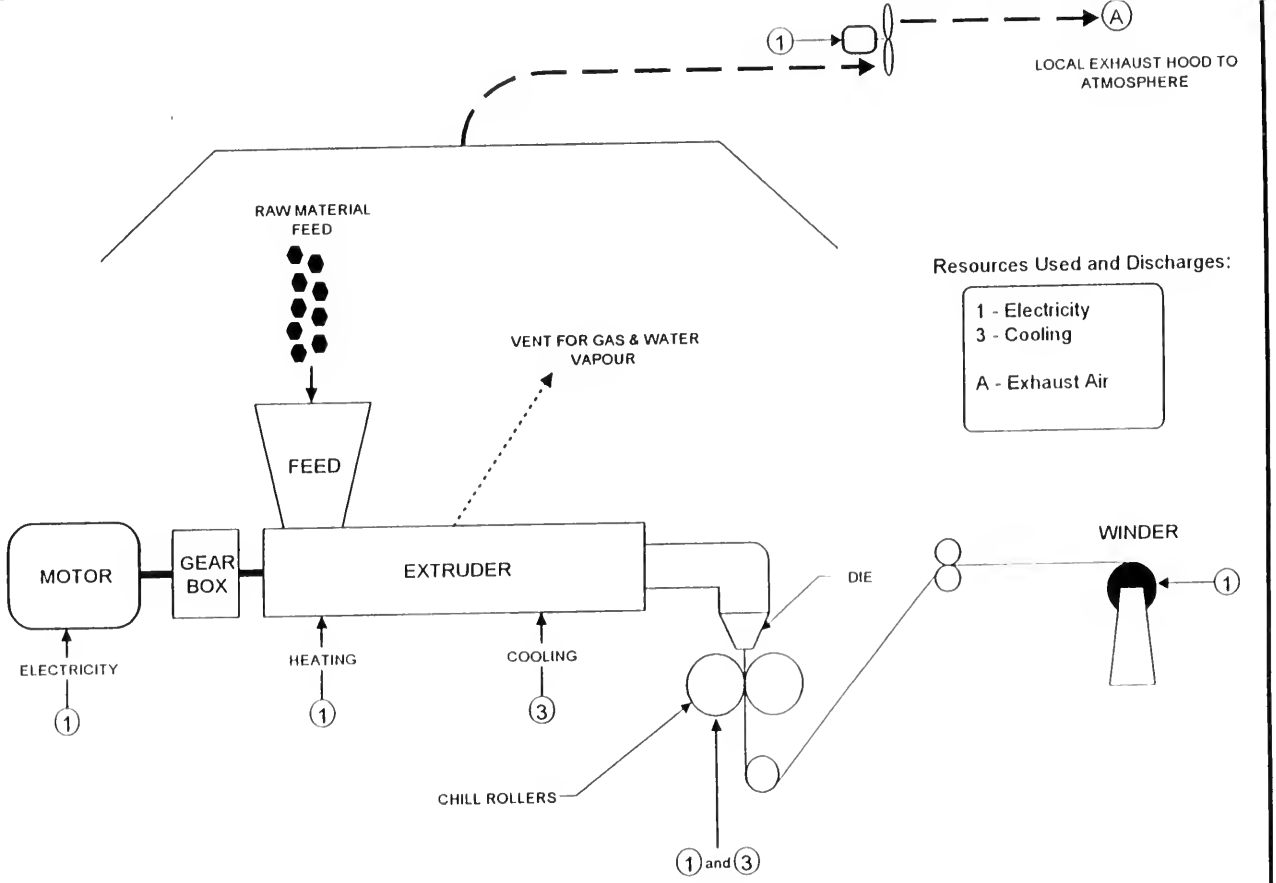


Figure 4-3: Resource Consumption and Emission Points in the Film or Sheet Extrusion Process

4.4 Blown Film Extrusion

In this process plasticized material is forced through a ring shaped die. Die diameters may range from a few centimetres to over two meters. The technology required to distribute the melt evenly around the die and to attempt to produce uniform film gauge thicknesses is complex.

The tube formed by the die is expanded into several times its original diameter by air pressure introduced through the die. Air blown from a ring outside the bubble, which may be several stories high, is used to cool the material from the outside. Both the external and internal air streams may be chilled. Automatic air rings may be used to allow individually controlled air streams to be directed at specific areas of the bubble. Automatic measurements of film thickness are used to feed back information to control the velocity and/or the temperature of the individual air streams.

Once the material has solidified, the bubble is passed through a collapsing frame into pinch rolls. These rolls permit a constant pressure to be maintained inside the bubble by preventing the loss of air which is introduced through the die. The air pressure is used to control the size of the bubble, and consequently the thickness of the blown film.

Products such as garbage bags are made from a single polymer. More complex products which require specific barrier properties, such as medical applications or food wraps, may be produced from as many as seven different materials co-extruded in a single process.

The blown film may be slit and wound on rolls as flat film. Alternatively, the film may undergo several additional processes in-line. It may be treated to improve adhesion for glues and inks, printed, gusseted, and cut into products such as grocery bags.

Throughputs in excess of 1500 kilograms per hour have been achieved.

Polyethylene is the most commonly used polymer for high volume blown film extrusion applications.

Resource Consumption and Emissions in the Blown Film Extrusion Process

The major energy requirement for this process is the electricity to drive the extruder screw motor. Significant energy is used to drive cooling fan motors and lesser amounts are required for winder equipment.

Water vapour and other gaseous emissions are released into the atmosphere from barrel vents, the feeder throat and the die area.

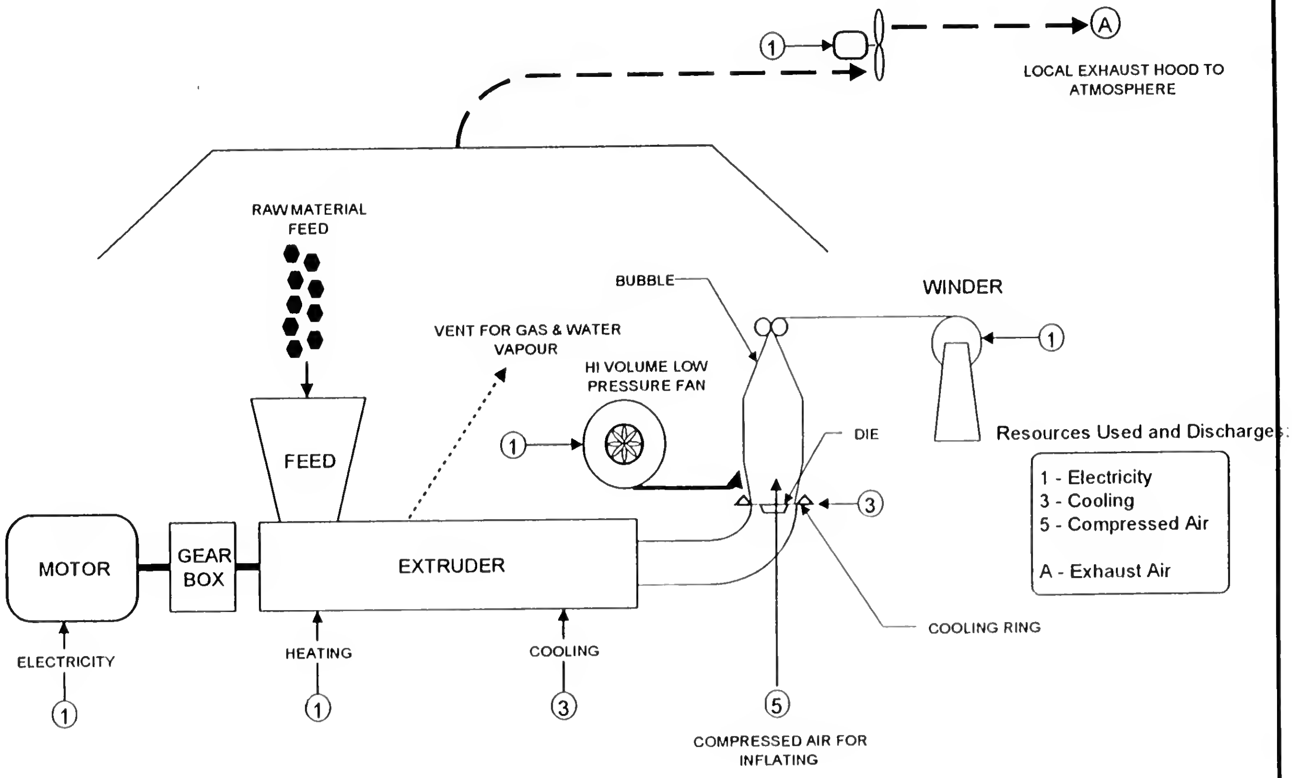


Figure 4-4: Resource Consumption and Emission Points in the Blown Film Extrusion Process

4.5 Blow Moulding

4.5.1 Extrusion Blow Moulding

In this process, a screw plasticizes material which is forced through a ring shaped die to form a tube of material, called a parison. For small parts, the extrusion of the parison may be continuous, in which case the maximum size of the part is limited by the tendency of the parison to stretch under its own weight. For larger parts, or more difficult to process engineering materials, the melt is collected in an accumulator system, and is injected intermittently by a plunger. Reciprocating screws, operating in the same manner as for injection moulding, may also be used to form a parison. To conform with product and process demands to have more or less material in specific areas of the part, moving mould components can be used to vary the thickness of the parison while it is being formed.

The parison of molten material is captured between mould halves. Air is injected into the parison to inflate the material into contact with the mould walls. After cooling, the part is ejected and trimmed of flash. Typically, multiple moulds are shuttled or rotated to allow cooling to take place while another mould is capturing the subsequent parison. Since the pressure exerted by the air which is used to expand the parison is relatively low, moulds can be made of aluminium. However, polished steel moulds are typically used for parts which require a good surface finish. Moulds may be either cooled or heated, depending on the materials used and the appearance requirements of the finished product.

4.5.2 Injection Blow Moulding

Large quantities of containers, such as bottles or jars, with a good surface finish and tight tolerances may be produced by injection blow moulding. This process typically utilizes a three station indexing table. The first station is used to injection mould a preform. At the second station, the preform is introduced into another mould and is blown to form the finished product. The third station is used for parts removal.

Alternatively, a preform may be produced in a separate injection moulding machine. For high volume applications, such as beverage containers, the injection mould may have over one hundred cavities. The preform is later re-heated and inserted into a blow moulding machine. This process permits more complex shapes and a more economical use of raw materials.

Polyethylene, polystyrene and polyethylene terephthalate resins (PET) are commonly used materials for packaging applications and beverage containers.

Resource Consumption and Emissions in the Blow Moulding Process

The major energy requirement for this process is the electricity to drive the extruder screw motor. Some electrical energy is used to drive mould transport mechanisms, whether electrically or hydraulically operated and to provide compressed air for blowing. In injection blow moulding, gas may be used to re-heat preforms. Cooling water, often recirculated, may be used for moulds.

Water vapour and other gaseous emissions are released into the atmosphere from barrel vents, the feeder throat and the nozzle. When gas is used for heating preforms, the combustion contributes to air emissions.

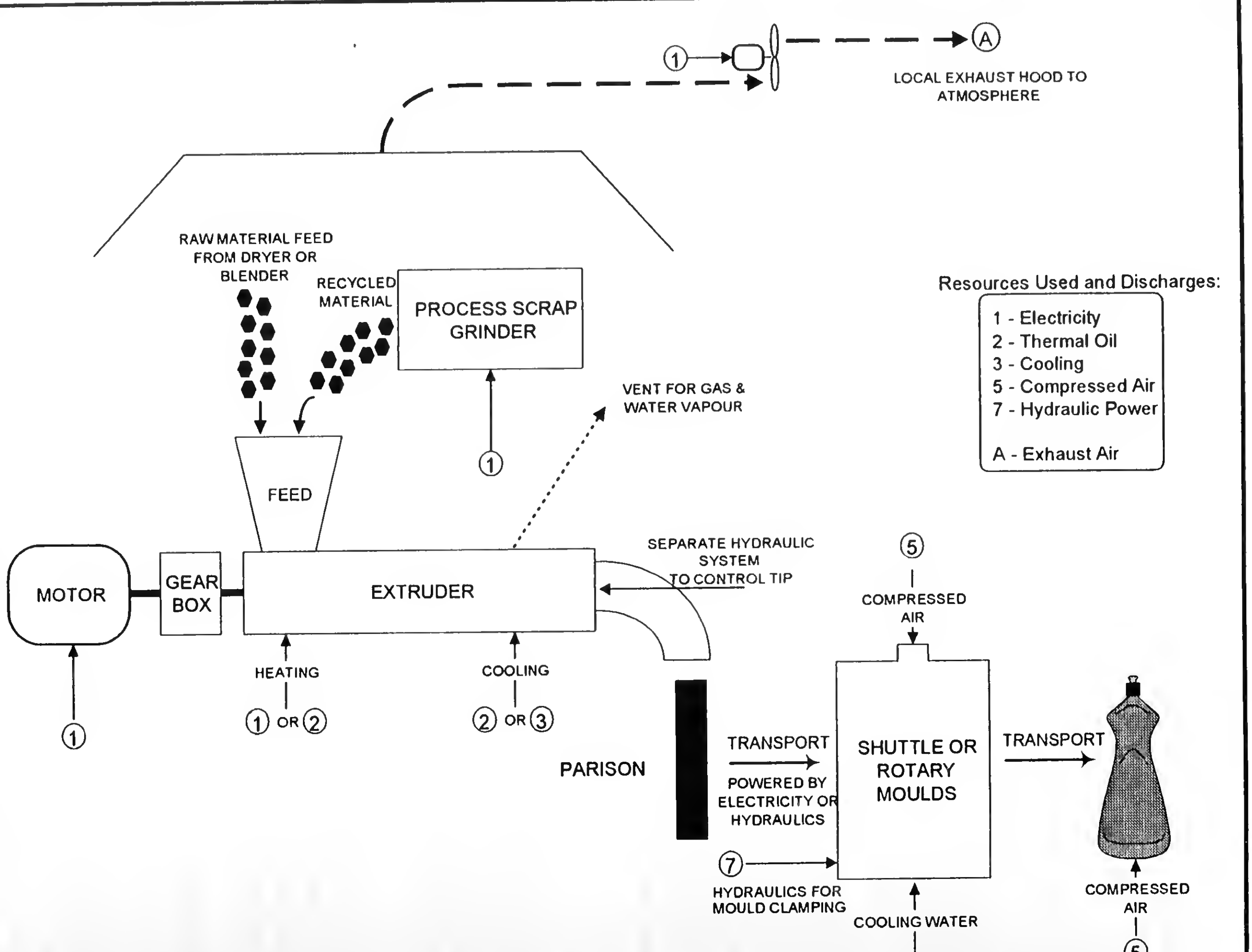


Figure 4-5: Resource Consumption and Emission Points in the Blow Moulding Process

4.6 Compression Moulding of Thermoset Plastics

Thermoset plastics behave differently when heated. These materials undergo an irreversible chemical process when heated and cannot be re-plasticized. The five processes described above commonly use thermoplastic materials. These soften when heated and re-harden when cooled. For most thermoplastics, this melting and cooling process can be repeated a number of times without a significant loss of physical properties.

Thermoset raw materials are supplied in either granular form, or as sheet moulding compounds (SMC), which are supplied in rolls of a putty-like sheet. Typically, sheet moulding compounds contain a proportion of glass fibres which impart improved physical properties to the end product.

In compression moulding, a pre-weighed amount of thermoset material is placed into a mould cavity. Some thermoset materials can be moulded at ambient temperatures. However, shorter cycle times are achieved by using heated moulds. The heated mould is closed under hydraulic pressure (often as high as 5000 PSI) and the material flows to fill the mould.

The clamping capacity of a large compression moulding machine may exceed 10,000 tons.

The low cost, low weight and high strength of glass filled compression moulded products has led to an increased penetration of this technology into many mass transportation and automotive applications.

Thermosetting polyesters, typically with added glass fibre, are commonly used in compression moulding applications.

Resource Consumption and Emissions in the Compression Moulding Process

The major energy requirement for this process is the electricity to drive the hydraulic system for the press. Energy is also required to heat the moulds, either directly through resistance heating, by thermal oil or by steam.

Emissions from the moulding compound are released into the air during the process. Oil leaks from the hydraulic systems may contaminate stormwater.

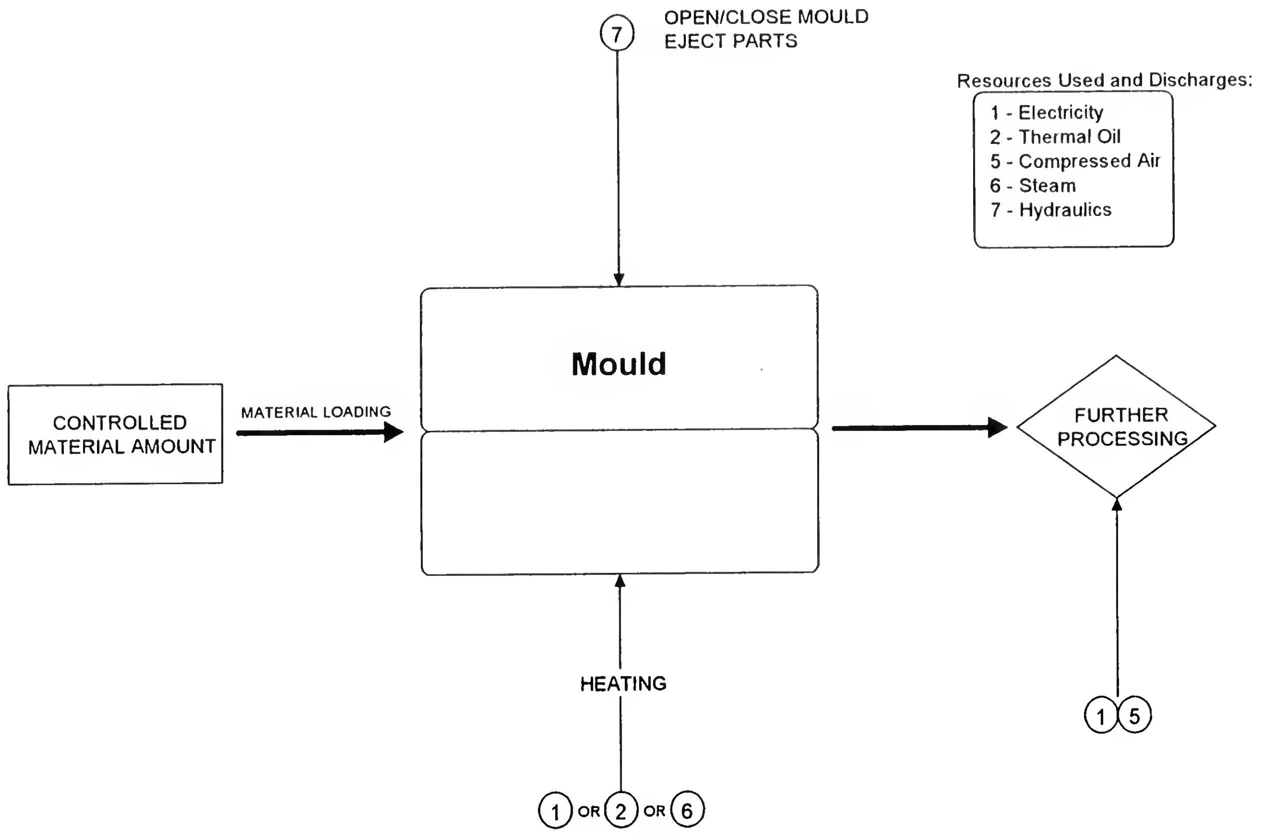


Figure 4-6: Resource Consumption and Emission Points in the Compression Moulding Process

4.7 Foam Moulding

The foam moulding process introduces a mixture of liquid raw materials into a mould. This mixture undergoes a chemical reaction and expands to fill the mould. For fast reacting foams, closed moulds are used in a process called reaction injection moulding (RIM). Slower acting foams may be poured into open moulds, which are then closed while the foam expands to fill the mould.

To ensure consistency in the finished product, a precise control of the raw material mixing is necessary. Low pressure mixing, used for filling open moulds, are capable of accurately metering and mixing ten different ingredients with shot sizes ranging from a few grams to hundreds of kilograms.

For high volume production, a single mixing head is used to fill a series of moulds which travel on a conveyor system while the foam cures. The moulds are opened at an unloading station and the finished parts are removed. For certain applications, inserts may be loaded into the mould.

A trimming operation is often required to remove unwanted flash from the parts.

The blowing agents and other chemical components may also be controlled to produce foams of various densities. Rigid foams are frequently used for insulation, while flexible foams are commonly found in furniture, car seats and energy absorbing padding.

Polyurethanes are the most frequently used family of materials.

Resource Consumption and Emissions in the Foam Moulding Process

The major energy requirement for this process is the electricity to drive the material dispensing systems. Lesser amounts are required for mould transport and for hydraulic mould operating systems, when used.

Most foam moulding processes do not use cooling water. However, the use of solvents to clean dispensing equipment may generate liquid wastes which need special handling. Air emissions include releases from the curing material, solvents and mould releases. Solid waste from the trimmings and other scrap are often recycled in carpet underpadding.

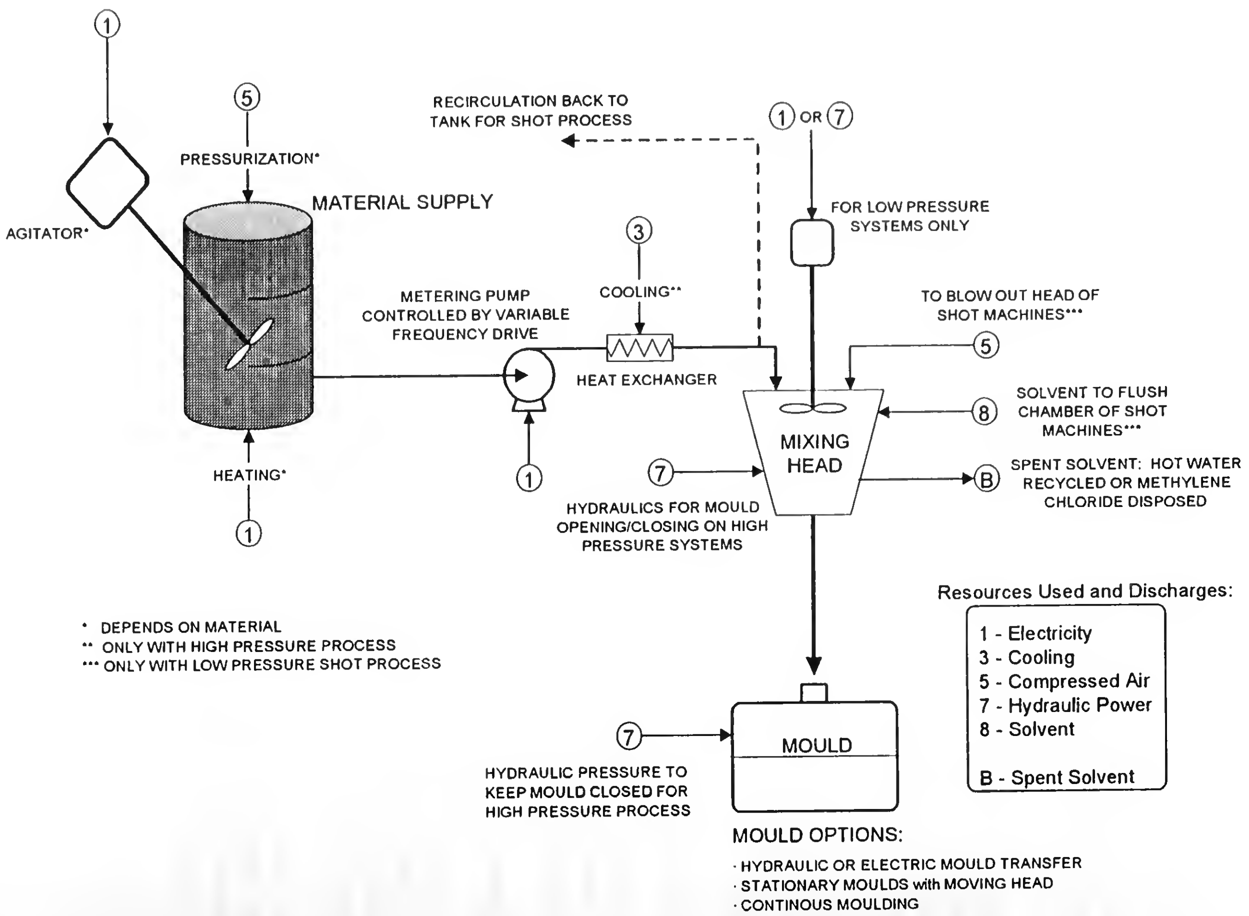


Figure 4-7: Resource Consumption and Emission Points in the Foam Moulding Process

4.8 Auxiliary Systems

In addition to the primary processes described above, most plants also utilize several auxiliary systems such as those listed below.

Cooling Systems - Once Through and Closed Loop

Once-through cooling utilizes line water to remove heat from the equipment or process prior to discharging to the sewer system. Closed loop cooling reuses the water by removing the heat that is absorbed from the process by circulating the water either through a chiller or a cooling tower.

Closed Loop "Free" Cooling System

A "free" cooling system uses ambient outside air to reduce chiller system energy requirements in cool weather.

Hydraulic Power Unit System

Hydraulic power units are comprised of a hydraulic pump usually driven by an electric motor. The pump pressurizes hydraulic fluid which in turn powers a variety of components such as hydraulic cylinders, hydraulic motors, etc.

Thermal Oil Heater/Cooler Systems

Thermal oil heater/cooler systems consist of a tank filled with thermal oil, a pump and either a heater or cooling element. The thermal oil is used to control the temperature of the equipment or process.

Compressed Air System

Compressed air is used for a variety of applications within a plant which includes powering cylinders, motors and actuators. The compressed air system consists of a motor driving a compressor which compresses air into a receiver. From there, the air typically goes through a dryer before being distributed throughout the plant to various applications.

Pneumatic Raw Material Handling System

A pneumatic raw material handling system is used for the transfer of larger quantities of materials such as pellets within a plant. In addition to the pneumatic conveying system, depending on the type of material, a mixing or blending system and a dryer may be included in the system.

The above mentioned processes are illustrated in Figures 4-8, 4-9, 4-10 and 4-11. Resource use and discharges are pinpointed in each of the auxiliary system illustrations.

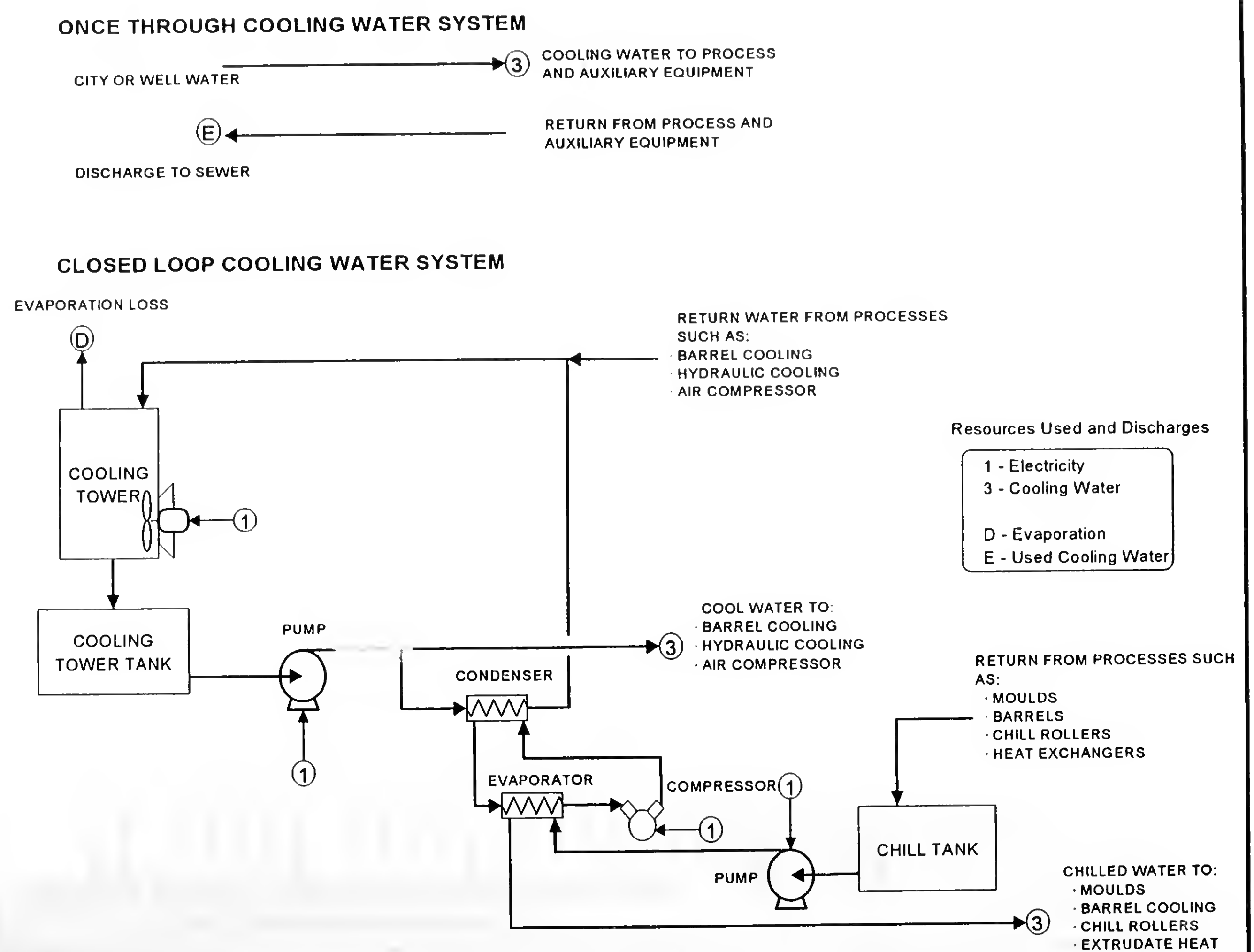
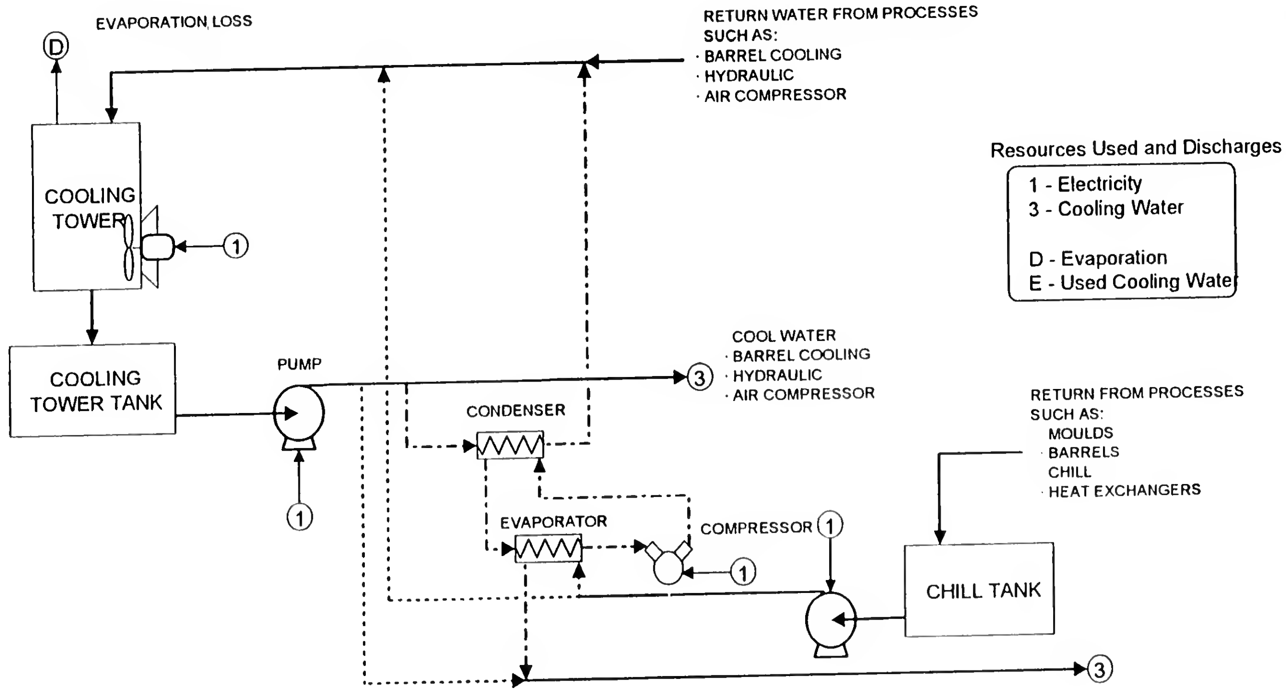


Figure 4-8: Auxiliary Processes - Once Through and Closed Loop Cooling Water Systems



To use 'free' cooling, the ambient temperature needs to be less than 13 degrees Celcius. The chiller portion of the cooling circuit denoted by -·· is by-passed with lines denoted by ···· to provide the required cooling through the cooling tower.

Figure 4-9: Auxiliary Processes - Closed Loop 'Free' Cooling Water System

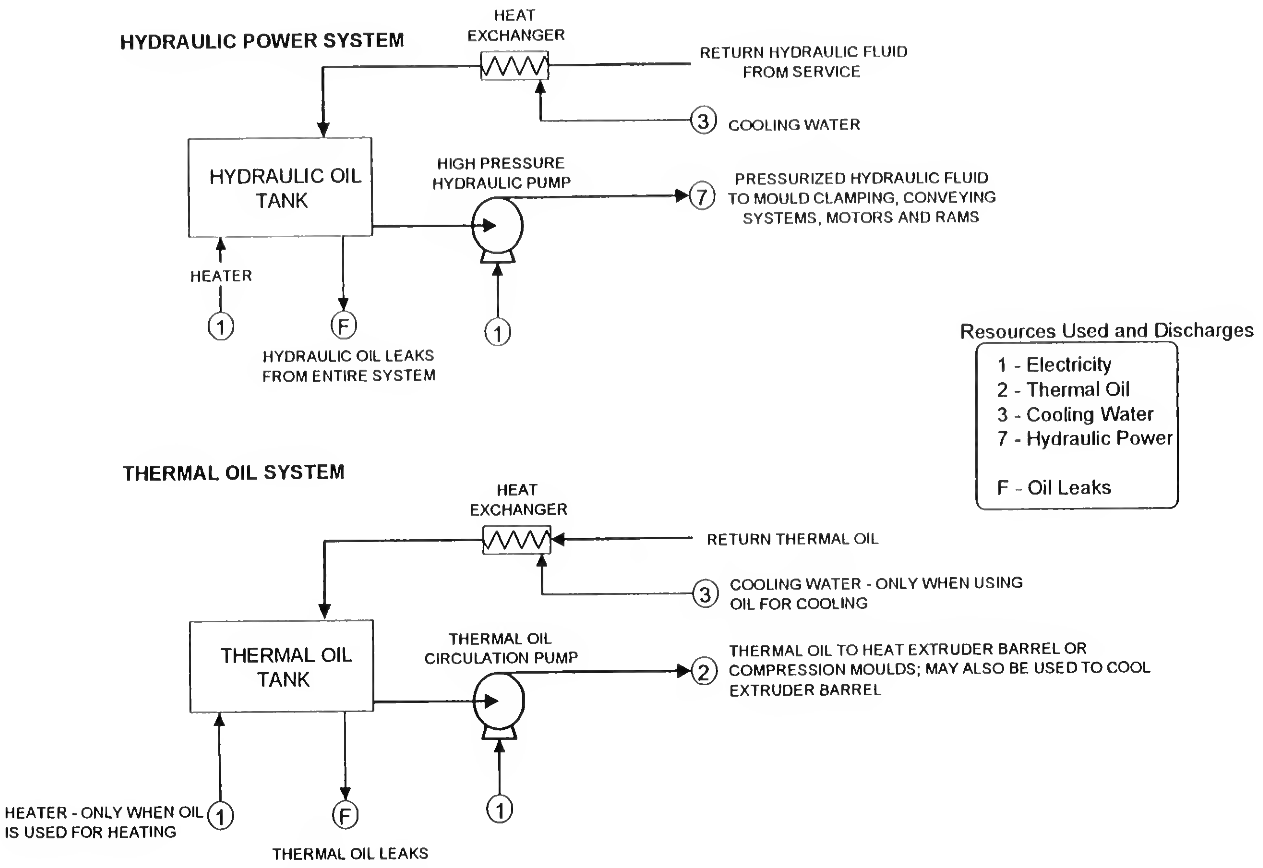


Figure 4-10: Auxiliary Processes - Hydraulic Power and Thermal Oil Systems

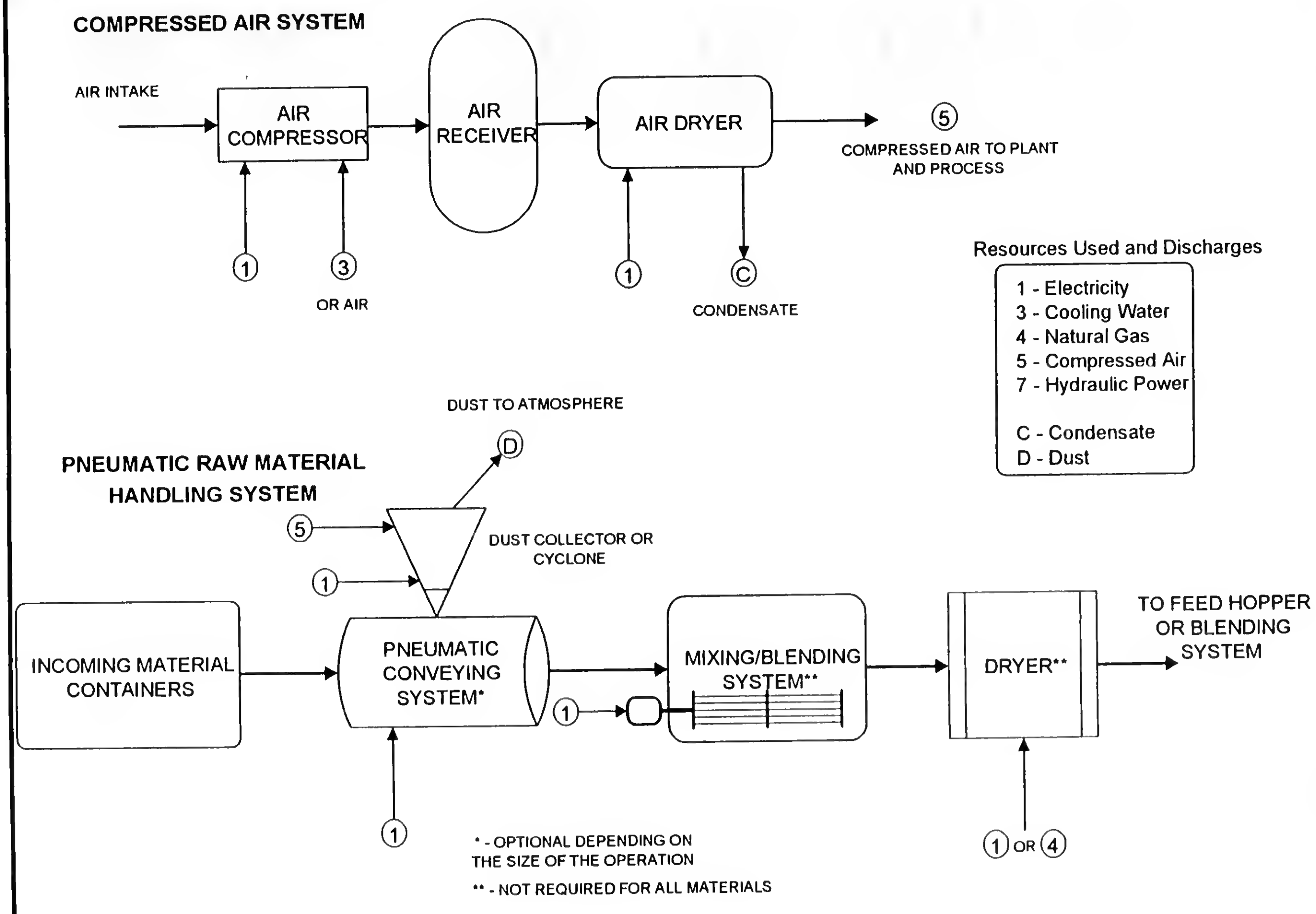


Figure 4-11: Auxiliary Processes - Compressed Air and Pneumatic Material Handling Systems

5. GENERIC IMPROVEMENT OPPORTUNITIES

Each plastics processing facility is uniquely designed and may use a variety of technologies to serve the needs of a specific market. As a result, there will be significant differences in processing conditions, energy and water use, and emissions levels. The opportunities in this chapter will need to be evaluated on an individual basis taking into account current operations.

Typical manufacturing expense breakdowns for injection moulders and film processors are illustrated in Figures 5-1 and 5-2 respectively. Most of the other processes discussed in this guide will have similar cost structures. This chapter deals with major cost saving and resource conservation opportunities in an order of probable cost impact. As illustrated in Figures 5-1 and 5-2, direct material costs typically constitute 50% - 70% of total manufacturing expenses. Material savings opportunities are discussed first, followed by energy, water and other resource conservation topics.

Process specific case studies of energy saving opportunities for injection moulding, extrusion and blow moulding plants are presented in Appendix IV. These studies also illustrate process, auxiliary equipment and plant savings opportunities for operations with various electrical power demands.

5.1 Material Conservation

Opportunities to reduce resin consumption by improved material handling and processing are discussed, in addition to enhancements in operating procedures and innovative business practices. Opportunities associated with plant maintenance, consumable supplies and packaging are also discussed. Resin conservation topics include:

- Better material handling and storage
- Enhanced processing conditions and handling of regrind
- Improved sales, purchasing and scheduling policies

5.1.1 General Plant Supplies

Plastics processors use a variety of cleaning and building maintenance supplies, common to all manufacturers. A significant reduction in the use of these supplies may be achieved by improved material handling, housekeeping and maintenance practices.

5.1.2 Consumables and Maintenance Supplies.

Typical consumable supplies in the industry include hydraulic oils, mould release agents and solvents. Reduction and potential substitution of these materials is discussed in Section 5.5, *Emissions Reduction*.

Figure 5-1: Total Manufacturing Expense Breakdown - Typical Injection Moulder

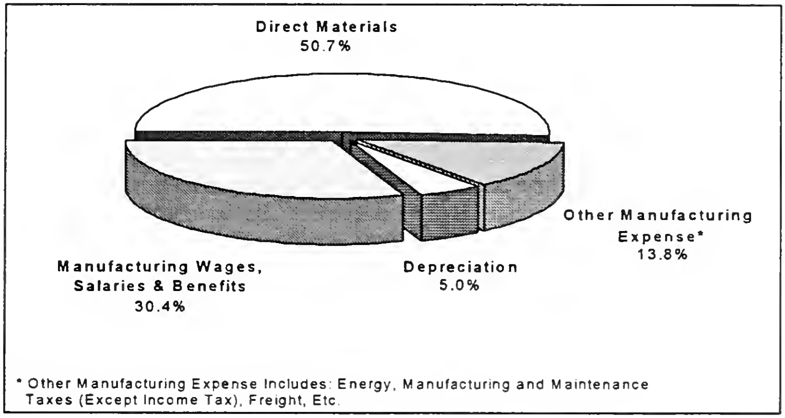
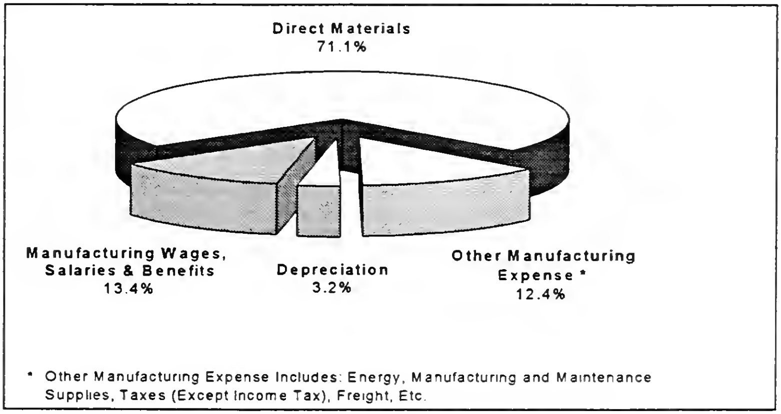


Figure 5-2: Total Manufacturing Expense Breakdown - Typical Film Manufacturer



5.1.3 Resin Conservation

In most plastics processing operations, material costs constitute by far the largest single portion of manufacturing expense. A reduction in resin use has an obvious direct cost benefit and also supports the processor's emission reduction objectives.

Large volume resin users, such as major siding and pipe producers, often compound resins in-house by adding lubricants, stabilizers and other processing aids and additives. This processing technology is not one of the major generic processes discussed in this guide. This guide assumes that the thermoplastic processors are receiving pre-compounded resins in pellet form.

Resin conservation is discussed under three major headings; 1) pellet control, 2) material use reduction in processing, and 3) regrind.

5.1.3.1 Pellet Control Program

Significant costs may be incurred through improper handling of raw materials. Savings may often be realized with little or no investment. A company policy which insists on an immediate clean up of all material spills, preferably by the individual responsible for the spill, encourages improved practices and reduces the frequency of spills caused by careless handling of materials. In support of this policy, a program to keep employees informed about the price of pellets increases awareness of this important issue. A reduction of pellet spills will also improve safety as pellet spills can constitute a significant safety hazard.

The following suggestions are offered to help prevent pellet loss and reduce costs:

Unloading from tank trucks or rail cars:

Material losses may occur during the sampling of incoming material, purging of lines and the transfer of pellets from a tanker truck or rail car to a plant silo.

- Tarps or containers should be provided to catch pellets and the unloading area should be paved to facilitate cleanup
- Trucks and rail cars should be inspected to ensure that they are completely empty after unloading

Warehousing and handling of material bags and gaylords:

- Containers should be inspected for damage and replaced or repaired during unloading
- Proper handling procedures, especially by forklift drivers, should be followed to minimize handling damage
- All partially filled containers should be clearly identified to minimize accidental mixing of materials
- All containers should be covered to prevent contamination
- All containers should be fully emptied prior to disposal/recycling

Material spillage and contamination during blending, drying and handling within the plant:

- Over-filling of pails and other containers should be discouraged
- Dryers and hoppers should be emptied and cleaned prior to material or colour changes

Guidelines for a comprehensive pellet handling program are available from The Society of the Plastics Industry, Inc., (202) 974-5200.

5.1.3.2 Material Use Reduction in Processing

The overall consumption of raw materials is influenced by many factors in manufacturing. Savings may be realized from both management policy changes and technical improvements.

Sales policies:

Many small custom processors serve markets which demand a vast variety of material specifications and colour options. It is typically very difficult to match material purchases precisely to the production quantities. At the end of a contract, the processor may have small quantities of materials left, with no current use. These assorted materials often accumulate for many years and are eventually sold at a loss, or sent to landfill. If possible, flexible shipping quantities should be negotiated with clients to ensure that non-standard materials are fully used.

Scheduling:

In most processes, start-ups and material or colour changes create material waste due to purging losses, mixing of resin types or colours during the changeover and a quantity of off specification product which is produced before the process becomes stable. The following scheduling practices will help to minimize these losses.

- Longer runs
- Continuous operation
- "Quick die change" practices
- Scheduling similar materials and colours together

Process conditions:

Material can be degraded due to overheating in the process. All materials should be processed in accordance with manufacturers' recommendations. Poor instrumentation, contaminated raw material and worn out or damaged screws and barrels also contribute to material degradation.

5.1.3.3 Regrind

Whenever possible, materials which can be reground should be processed during the production run and fed directly back into the process. This eliminates multiple handling, risk of contamination and the opportunity for hygroscopic materials to absorb moisture.

5.2 Energy Conservation

In the majority of processes discussed, a significant percentage of the total energy demand is consumed by the extruder drive system. Variable speed drives discussed in this chapter have shown energy savings of up to 20% in some extruder drive applications. Mould clamping system energy savings of up to 45% are achievable by using a combination of technologies.

The *Canadian Industry Program for Energy Efficiency (CIPEC)* has published detailed studies of ***"Energy Efficiency Opportunities in the Plastics Industry"*** for three key processes; 1) Extrusion, 2) Injection Moulding and 3) Blow Moulding. These studies also cover auxiliary and plant systems. A significant portion of the savings may be achieved without significant capital spending.

Several excerpts from the CIPEC study are tabulated in Table 5-1. A more complete summary of the highlights of the CIPEC study is found in Appendix IV.

Table 5-1: Major Energy Savings Opportunities - Process Equipment

Process	Energy Saving Technique	Potential Saving %
Extruder drive system	Specify correct size and speed of motor for application. Investigate high efficiency motors.	20
Extruder barrel heating	Insulate extruder barrel.	15
Mould closing, transport and clamping systems	Use variable hydraulic power to match load requirements. May be achieved by using variable speed drives, variable displacement pumps, accumulators and control system.	45
Centralized hydraulic system	Arrange for one central hydraulic power system to supply a group of machines.	50
Compressed air system operation	Ensure system is correctly sized, well maintained and that the compressors are "staged."	20

5.2.1 Specifying Energy Efficient Equipment

Historically, many new equipment purchases have been evaluated on the basis of capital cost, installation cost, throughput, and projected maintenance expense. Energy costs and resource utilization issues have received less attention.

Today, most machinery and process equipment vendors are well prepared to discuss projected energy costs. While the data presented by vendors typically describes ideal operating conditions, comparisons of energy efficiency are possible in most cases and should be factored into the purchasing decision.

Other important criteria which may be easily be overlooked include:

- Noise levels
- Access for maintenance and spill clean-up
- Ease of housekeeping ease
- Safety

5.2.2 Replacing Inefficient Equipment During Maintenance

Many opportunities for improvement can be missed when maintenance is carried out under emergency conditions. The normal tendency is to replace existing equipment with an identical spare. For example, a burned out electric motor represents an opportunity to evaluate the benefits of replacement with a high efficiency unit. The economics may not favour replacing a working motor with a high efficiency one, but the calculations may show a good payback if the original has failed and requires a replacement.

Significant savings may also be achieved at little or no cost by following a regular, well-documented maintenance program. Proper maintenance procedures and schedules are generally available from equipment manufacturers. A well documented program would schedule and co-ordinate inspection and preventive maintenance of equipment and housekeeping procedures instead of running equipment until it fails.

5.2.3 Motors

When purchasing new equipment or replacing worn-out motors, consider specifying high-efficiency motors especially in high load or high running hours applications.

Motor should be sized to operate between 75% to 100% load. For non-critical applications with constant load such as fans, size as close as possible to 100%. Do not oversize in anticipation of more capacity unless this requirement is reasonably predictable. Oversizing results in higher capital cost for the larger motor, cabling and starters, and incurring higher operating costs due to a power factor penalty.

Advantages of a high efficiency motor:
Operating savings from:

- Improved power factor
- Reduction or elimination of power factor penalties
- Reduction or elimination of capacitors used for power factor correction
- Less heat generation resulting in longer life and lower cooling requirements for motor

Payback calculation:

kW Saved = HP x 0.746 x (1/Std. Eff. - 1/Hi-Eff.)

HP = Mechanical Power Requirement

$ Saving = kW Saved x Annual Operating Hours x Average Energy Cost

Payback = $\dfrac{\text{Price Premium for Hi-Eff Motor}}{\text{\$ Saving}}$

Suppliers of high efficiency motors report that more than 20% of their sales are for retrofit or replacement applications.

5.2.4 *Variable Speed Drives*

For applications with varying loads such as fans, blowers and pumps, variable speed drives (VSD's) should be considered for installation. The advantages of using VSD's include:

- energy savings of 10 to 40% over constant speed motors, depending on the application
- reduced wear on the motor by running at reduced speed and torque for reduced capacity conditions
- gentle starting which reduces power surges and wear on mechanical components

In addition, VSD's can improve the process in applications that require control of the speed of rotation of components. An example is screw drives to maintain proper feed rates.

VSD's can also replace traditional damper controls for controlling gas flow rate, allowing centrifugal fans and blowers to operate over a wider range without the danger of surging. Pumps too can be operated over a wide range by controlling the pump speed instead of throttling the flow with control valves. Other advantages of VSD's are reduced cooling costs, plant noise, and wear on the motors and the equipment they are driving.

Software to calculate energy savings is available for free either directly from vendors or by downloading it off the Interment from their web sites.

There are various types of VSD's: silicon controlled rectifiers (SCR's) with DC motors, variable speed (VS) AC drives and Brushless DC (BDC) drives. SCR systems are not as efficient as the other two types plus the SCR DC system is maintenance intensive. The most efficient is the BDC but its cost is higher then that of the AC drive.

The advantages of BDC's includes a greater speed range, much more precise speed regulation, full torque capacity, higher efficiency rating, smaller size for the same horsepower and lower maintenance. The power factor is also higher than that of AC induction systems.

5.2.5 *Hydraulic Pumps*

- Need to be operated at >75% capacity; otherwise a severe energy penalty is incurred.
- Do not use pressure compensating pumps; wasteful of energy.
- Use variable volume (displacement) type of pumps or multiple, independently driven, fixed displacement pumps. This option requires PLC control equipment and good maintenance to run properly.

5.2.6 Hydraulic Systems

- Use accumulators, especially for injection moulding.
- Whenever possible, power multiple hydraulic motors and cylinders from a single, central hydraulic system, especially a group of injection moulding machines. In this way the power requirement of the multiple machines tends to be smoothed out; maintenance costs are also reduced.
- By operating multiple machines from a single hydraulic system, a sophisticated control system is not required. Also older machines can take advantage of considerable energy savings without having to retrofit their components.
- In setting up a single hydraulic system, segregate machines or functions into similar pressure requirements; may need to add load sensing device if pressure requirement is not continuous.
- On injection presses, there should be two cylinders - a small diameter, long stroke cylinder for mould transport and a large diameter, short stroke cylinder for clamping the moulds.

It is often difficult to justify upgrading hydraulic systems and components based on energy savings alone. Improvements in productivity, quality as well as decreased maintenance costs must also be considered.

As a rule, retrofitting older existing equipment may not be effective if the machines are small or modifications are not easily made. Buying new equipment with energy efficient components, controls and mode of operation may be more cost effective. It is important to ensure that the energy penalty from older technology is understood and that the implications are considered when future equipment purchasing decisions are made. If there are several machines available for production, it would be beneficial to consider using the most energy efficient equipment if production schedules permit.

5.2.7 Machine Components

- Replace worn out components, such as valves, with more efficient products.
- On injection moulding machines with vane type hydraulic motors, efficiency decreases if the motor is run at less than 80% of rated speed. To improve speed range, install a two or three speed gearbox. Alternatively, replace the vane hydraulic motor with direct coupled piston type of hydraulic motor which is efficient over the entire speed range. A more expensive option is to install an electric variable speed drive. The cost of power electronics have declined and under some circumstances this option may be economically viable.

5.2.8 Screws and Barrels

A high percentage of the total energy requirement (up to 30%) for moulding and extrusion equipment is used to plasticize material. Screw design is the most important feature on extrusion/injection machines. Screw design technology is constantly evolving and many vendors can provide information on the appropriate screw diameter, geometry and Length to Diameter ratio appropriate to a specific material and plasticizing rate. Energy savings of 20% are claimed in some instances. If the machine utilization rate is high and the production demands are predictable, a screw replacement may be warranted. Screws and barrels should be checked every five to six months. Replace or repair worn screws as the payback is quick, in the order of a few weeks.

Heater bands account for approximately 14% of the energy used. It is recommended that the barrel be properly insulated which will result in both energy savings and a more easily controllable melt temperature. Insulation should not be used over mica heater bands as the insulation will reduce their operating life.

5.3 Water Conservation

Processors who use significant amounts of process cooling water, the following system design considerations and calculation formats may be used to evaluate the savings available from a variety of recirculating systems versus using line water on a once-through basis.

5.3.1 System Design Considerations

Government statistics indicate that the plastics processing industry recirculates approximately 87% of its water requirements. This chapter will assist processors who are using cooling water on a once-through basis to evaluate the savings opportunities available for their process. The potential for cost savings depends on several factors such as:

1. The amount of water used as once-through non-contact cooling water (m^3/h or gpm)
2. The associated cost of cooling water. Water costs involve both the cost of the supply water, and the sewer discharges associated with disposing of the water. The water costs in Ontario vary between \$0.38/m^3 to \$1.01/m^3.
3. The heat load of the operating equipment based on hours/year.
4. The cooling water temperature required.
5. Capital cost of the cooling water recycle system.
6. Operating cost of the cooling water system.
7. Cost of make-up water

The water must truly be "non-contact" water in order to be recycled. Quite often a 'blowdown' stream is required and chemical additives are required to control water pH, hardness, bacterial growth and suspended solids. This 'blowdown' stream would be pumped to a sewer and therefore a small amount of make-up water is required. The amount of blowdown and make-up in this system should be minimal and will vary with every system.
There are three basic cooling systems that can be implemented:

1. Portable chiller for small heat loads (0-9 tonnes heat load)
2. Permanent chiller or cooling tower for medium heat loads (9-36 tonnes heat load)
3. Permanent chiller and cooling tower for large heat loads (36 + tonnes heat load)

Medium heat load applications may be able to use a chiller or a cooling tower depending on the process and the volume of water and cooling water temperature required. A situation with high cooling water temperature but low cooling water volume requirements may suit a cooling tower system. This is due to the high operating costs of a chiller which would offset the savings in water usage costs.

5.3.2 Calculations

Cooling Water Usage and Heat Load
This section allows you to calculate the cooling water heat load.

Type of Cooling: ____

Cooling Water Flow rate: _____________ m^3/h.

Temperature of Cooling Water Required: ____________ °C

Temperature of Cooling Water After the cooling application: _________ °C

Difference in Temperature (ΔT) = Temperature of Cooling Water Required - Temperature of Cooling Water After the cooling application
= _________________ °C - ________________ °C
= _________________ °C

Heat Load (Tonnes) = [Flow Rate (m^3/h) x ΔT (°C)] / 3
= [_________(m^3/h) x ____(°C)] / 3
= __________________ Tonnes

Water Costs

This section allows you to calculate the annual water costs spent on cooling water.

Municipal Water Costs = $________________/m³ (including sewer surcharge)

Amount Water Used /Year = ____m³/h x ___ hours/day x ___days/week x ____weeks/year
= _______________ m³/year

Annual cost of water = $________________/m³ x ______________ m³/year

Chiller Costs and Payback Period

Look at the Heat Load (Tonnes) calculated above to determine the type of chiller most appropriate to the application from the information in Table 5-2.

Table 5-2: Appropriate Cooling Systems for Determined Heat Load Ranges

Heat Load (Tonnes)	Chiller Type	Approximate Cost
1-9	Portable Chiller	$5,000-25,000
9-36	Permanent Chiller or Cooling Tower	$20,000-$90,000
36+	Chiller and Cooling Tower	$90,000 +

Examples of heat loads, energy requirements and costs can be seen in Table 5-3.

Table 5-3: Examples of Heat Loads, Energy Requirements and Costs

Heat Load (Tonnes)	Chiller Type	Energy Requirement	Approximate Cost
6.75	Portable Chiller	14 kW	$16,000
27	Permanent Chiller	45.9 kW	$60,000
27	Cooling Tower	6.5 kW	$40,000
90	Chiller and Cooling Tower	62.5 kW	$140,000

Net Savings

This section will allow you to calculate the net savings for the implementation of a cooling system. The numbers given in Table 5-2 are typical examples and can be used for reference to this section if necessary. As discussed above, the cost of make-up water should also be considered.

Calculate the approximate energy costs per year.

Base energy cost = $________________ (approximately $ 0.06 / kWh)

Electrical Energy Requirement = ________________ kW (from the table above)

Energy Cost = Base Energy Cost x Electrical Energy Requirement X Hours of Operation/Year

=$_________ x ________ kW x ___ hours/day x ___days/week x ____weeks/year

=$ __________/year

Net Savings = Annual cost of water - [(Chiller operating cost) + (Make-up water cost)]

Payback Period

This section will allow you to calculate the simple payback period on the cooling system.
Payback Period = approximate cooling system cost / net savings

= $ _______________/ ($ ________________/ year)

= __________ year (s)

5.4 Auxiliary Systems and Facility Equipment

This section addresses significant opportunities related to auxiliary system efficiency.

Table 5-4 contains excerpts from the CIPEC study in Appendix IV. These figures illustrate savings opportunities for various auxiliary systems.

Table 5-4: Energy Savings Potential in Auxiliary Systems

Auxiliary System	Energy Saving Technique	Potential Saving %
Material dryers (electrical)	Use high efficiency electrical dryers	30
Material dryers (natural gas)	Use gas fired dryers for high volume applications (Typical for PET)	70
Dew point monitoring	Install dew point monitors on dryers	20
Air compressor operation	Ensure system is correctly sized, well managed. If capacity is sufficient, stage compressors.	20

5.4.1 Dryers

To provide good drying conditions, a dryer should provide: adequate drying temperature and dewpoint for the quantity of air used; adequate residence time for all the resin passing through the hopper; and good air flow distribution through the hopper.

Gas-fired Dryers:
Several manufacturers offer modular, natural gas-fired dryers and claim energy cost savings from 60-80% over electric systems. Gas-fired heaters may also be retrofitted to existing electric dryers at about 50% of the original price. Mechanically, the units are virtually identical to electric dryers. However, heat exchangers may be employed to maintain proper moisture levels to compensate for water that is generated in the combustion of gas. While capital costs may be higher than of electric dryers, manufacturers claim payback periods averaging about twelve months for high volume applications.

Two-Stage Dryers:
Two-stage systems, incorporating a drying oven and a dehumidifier, may be used to dewater hygroscopic resins while raising their temperature for subsequent melt processing. Manufacturers claim such systems are energy efficient, especially if waste heat from one dryer is reclaimed through a heat exchanger and re-used in the second. Two-stage systems can extend the life of dryer components (such as the desiccant in the second-stage dryer).

Smaller Heaters:
Instead of central heating systems, smaller, independently controlled heater elements may be installed in each drying bin, avoiding energy loss along pipelines or conduits. Other systems combine drying and conveying into a single unit.

Microprocessor Controls:
Drying is another area where the application of microprocessor control can result in significant process improvements. Dryers are often operated at less than their maximum rated capacity using more energy than required to remove moisture. With recently developed microprocessor control, temperature and dewpoint sensors installed at strategic locations in each dryer provide data input to a drying profile programmed for the specific resin being processed. he target profile automatically controls hot air flow, triggers replacement of desiccant cartridges and maintains the dewpoint and drying temperatures to optimize the actual material throughput and the drying conditions in the unit. However, at its present level of operational reliability, it is wise practice to supplement microprocessor control with periodic manual checks to ensure proper operation.

Insulation:
The hopper or drying bin, as well as any connecting hot air conduits, may be enclosed in an insulating blanket to prevent heat loss.

Energy Recovery:
The heat from the exhaust side of drying bins can be recovered through a heat exchanger and used for general plant heating, preheating incoming air, preheating material sent to an extruder, or heating material in other drying/dehumidifying bins.

5.4.2 Electrical Systems

The potential energy savings from correctly specified motors has been discussed above. Further opportunities may be found by examining the plant electrical demand as a whole. The plant electrical costs are usually based on:

- peak electrical demand (kW)
- energy consumption (kWhr)
- power factor penalty

The peak demand often occurs at a predictable time of day and may be reduced by shutting off non-essential equipment during that period, re-scheduling operations or by improving the efficiency of the operation. Reduction of consumption is discussed elsewhere in this guide.

A poor power factor is typically caused by under loaded AC induction motors, transformers and lighting ballasts. Utilities usually charge a power factor penalty to customers whose power factor is less than 90%. The common cost effective solution for power factor correction is the addition of capacitors to the system.

5.4.3 Compressed Air Systems

The following suggestions will help to increase the efficiency of compressed air systems and to reduce the cost and consumption of compressed air:

- Avoid air leaks - even a small leak generates significant costs
- Operate at the lowest possible pressure
- Use adequately sized piping to reduce pressure drops
- Avoid water accumulation in the system
- Draw cool air from outside the plant and minimize pressure drop in intake line
- Use engineered nozzles instead of pieces of pipe
- For multiple compressor units, investigate installing a control system that will sequence units based on pressure requirement and operating priorities

5.4.4 Lighting

The following guidelines will assist in reducing electrical demand in lighting systems:

Reduce the number of fixtures to a level that is adequate to the job

Historically, many lighting systems have been over-specified. A reduction in the number of fixtures, bulbs or tubes will often reduce energy costs while maintaining adequate lighting levels. Surplus ballasts should be removed if fewer fluorescent fixtures are required; ballasts draw energy even when the fluorescent tube is removed.

Use more efficient technology

Replace existing incandescent lamps with high efficiency fluorescent, halide or high intensity discharge lamps. Fluorescent lamps are typically 1.5 to 2 times as efficient as incandescent and high pressure sodium lamps are 1.5 to 2 times as efficient as fluorescent lighting.

Lights should be turned off when not required

Timers, occupancy sensors or photocells will assist in reducing energy costs by turning off or dimming lights. As a general rule, incandescent lights should always be turned off when not required, fluorescent lights when not required for more than 15 minutes, and halide or high intensity discharge lamps if not required for more than one hour.

5.4.5 Process Insulation

Thermal insulation on process equipment and piping results in the following benefits:

- Prevention of heat loss
- Assists in maintaining consistent process temperatures
- Prevents condensation
- Assists in maintaining a comfortable and safe workplace

5.4.6 Building Heating, Cooling and Ventilation

Many plastic processes and auxiliary systems emit heat. It is sometimes cost effective to capture process heat with suitable heat exchangers or blow heated air from areas such as a compressor rooms and to use this waste heat to supplant facility heating requirements. Thermostats may be programmed to reduce the heating load during off hours. Other cost saving methods include:

Reducing excess air infiltration

- Improve caulking and weather stripping around doors and windows
- Install air locks and air curtains
- Install low leakage dampers

Adequate ventilation may be obtained by following the guidelines published by the American Society of Heating, Refrigerating Air Conditioning Engineers (ASHRAE).

Destratification

Energy savings may be achieved during the winter heating season by preventing stratification; the tendency for warm air to rise and collect near the ceiling.

- Install ceiling fans
- Introduce make-up air near the ceiling level
- Use radiant heating

5.5 Emissions Reduction

The reduction of emissions from plastics processing operations is best achieved through carefully designed programs to optimize all aspects of the manufacturing process, particularly with respect to the use of raw materials including energy and water. Continuous improvement is best achieved through the implementation of an effective environmental management system (EMS). In addition to further discussion on EMS, other energy improvement opportunities are also discussed which focus specifically on material conservation, energy conservation, water conservation, auxiliary systems and facility equipment and case studies relevant to the plastics processing sector.

5.5.1 Air Residuals - Gases and Dust

Greenhouse gas emissions (i.e. principally CO_2) can be reduced by ongoing improvements in energy efficiency. Improvement opportunities are outlined in Section 5.2 entitled "Energy Conservation." These have the dual effect of both improving energy efficiency and reducing CO_2 emissions per unit of product processed.

Care must be taken to ensure that resin manufactures' recommended processing temperatures are not exceeded. Vendors' material safety data sheets (MSDS) should be consulted for appropriate processing procedures, precautions and engineering controls. For many materials, local exhaust hoods are recommended near areas where materials are heated.

The CCME guideline provides a number of suggestions for reducing VOC emissions such as the following; assess the technical and economic feasibility of using raw materials containing low levels of VOCs; investigate the feasibility of using alternative cleaning equipment and techniques; ensure equipment in contact with VOC containing material is well maintained and monitored to avoid leaking of emissions from material and to give immediate attention to replacing any defective parts; and, use appropriate methods to store, handle and dispose of solvents to minimize emissions. In addition to the above-mentioned suggestions, specific recommendations are also given for each of four targeted generic processes.

It is good management practice to conduct periodic air sampling surveys within the plant. Air sampling surveys serve the dual function of identifying air emission issues which may need to be addressed and also indoor plant air quality issues in relation to Ontario's Occupational and Health standards. This sector guide does not address occupational health and safety issues specifically but for general interest the complete reference for health and safety considerations is found in Chapter 8.

Fugitive dust levels may also be reduced through the use of collection systems located in close proximity to key locations within facilities such as material handling areas as well as locations dedicated to blending and grinding operations.

5.5.2 Wastewater and Liquid Wastes

The recirculating of cooling water has been discussed in a previous section. The discharge of wastewater to a sanitary sewer system is regulated under municipal by-laws. To minimize the risk of contaminating wastewater discharges, engineering controls and a spill prevention plan should be put in place. Typical preventive measures include:

- Oil interceptors for plant discharges
- Blocking building drains in areas where spills are likely
- Secondary containment for storage tanks

Good housekeeping practices will reduce the introduction of particulates into the sanitary sewer system. Properly engineered oil separators should be installed if oil spills are likely. Whenever possible, floor drains within the plant should be capped or sealed to contain minor spills.

Secondary containment should be provided for storage tanks containing petroleum products or hazardous chemicals.

Liquid wastes which require special handling commonly generated by the plastics processing industry include used hydraulic oils, spent solvents and other chemicals and should be properly stored and disposed of in accordance with provincial regulations.

Municipalities regularly sample plant discharges. However, they often fail to inform the manufacturers of exceedances; it is incorrect to assume that the operation is in compliance if no complaints are received.

5.5.3 Solid Waste

Source separation programs should be instituted for cardboard, steel, fine paper, glass and corrugated cardboard. Many companies already recycle packaging materials. Used gaylords are in demand by many industries for use as storage containers.

A number of Ontario firms specialize in recycled plastic materials. Clean pellets or regrind may be sold to these companies for re-pelletizing or re-sale. The Ontario Waste Exchange may be contacted as a potential resource when exploring markets for recyclables.

5.5.4 Noise

A noise survey should be conducted to identify areas which may exceed Occupational Health and Safety Regulation limits. Engineering controls should be used to reduce noise levels, whenever possible. Personal protective equipment must be supplied if controls are not feasible and should be provided in areas where employee comfort can be increased.

5.5.5 Stormwater

Stormwater, if it is discharged into a ditch, or another "surface watercourse" may fall under Federal or Provincial jurisdiction. The limits on contaminants are typically more strict than for sanitary sewers. A stormwater management plan should be in place to reduce the risk of contamination.

5.6 Environmental Management Systems

Well designed environmental management systems, such as ISO 14001 and resource conservation programs will assist processors to achieve the objectives of minimizing the impact of plant operations on the environment and reducing costs.

An environmental management system (EMS) is that aspect of an organization's overall management that addresses the immediate and long term impact of its products, services and processes on the environment.

An EMS is essential to the organization's ability to anticipate and meet growing environmental performance expectations and to ensure on-going compliance with municipal, provincial, national and international requirements. Evidence of an effective EMS has become an important part of obtaining corporate financing and helps to maintain real estate property values.

The ISO 14001 EMS standard provides an internationally recognized structure for developing and maintaining environmental systems. In many ways, it complements the well known ISO 9000 series of quality standards.

ISO 14000 series standards involve the elements listed below (many of these standards are still under development):

Environmental Management Systems
Environmental Performance Evaluations
Environmental Auditing
Life-Cycle Analysis
Environmental Labelling
Environmental Aspects in Product Standards

A detailed listing of the ISO 14000 series standards can be found in Appendix II.

Setting up and Managing an Environmental Management System.
The effectiveness of an Environmental Management System may be improved by applying common management principles which can contribute to the success of any project:
- top management commitment
- clear definitions of responsibility and accountability
- well defined, realistic goals
- effective program planning and implementation

Most successful programs start with an audit. The audit determines how the environment is impacted by plant activities, how resources are being used and identifies possible opportunities for improvement and for savings. Some plants have the internal resources to conduct an audit. Assistance and publications are available from utilities and government sources. If the environmental impacts are significant, resource consumption is high, or if a preliminary assessment shows significant savings potential, the opportunity may be pursued by using internal resources, or with the assistance of a consultant specializing in the field.

A reduction in the use of resources supports the objectives of Environmental Management Systems. Lower resource use typically has a favourable impact on reducing environmental effects.

5.7 Case Studies in Resource Conservation

The following case study summaries illustrate some of the successes achieved by plastics processors who have implemented specific resource conservation measures. For readers interested in more details, the sources for these case studies appear in Appendix V.

Material Conservation

A US company reduced film and pellet scrap generation by 88%, resulting in an annual saving of $72,000.

Energy Conservation

Results from two significant energy conservation studies are reproduced in two of the appendices to this guide (Appendix I and IV):

> Summary information from energy audits of 67 Ontario plastics processing facilities conducted by the Ministry of Environment and Energy are found in Appendix I. The study demonstrated rapid paybacks from improved technology and from heat recovery.
>
> Extrusion, injection moulding and blow moulding savings opportunities are examined in detail for Energy, Mines and Resources, Canada in 1993 by Power Smart, Inc. in Appendix IV. Portions of this study were published by the Canadian Plastic Institute (CPI) under the Canadian Industry Program for Energy Conservation (CIPEC). Process specific summaries of energy efficiency opportunities are reproduced in Appendix IV.

Water Conservation:

In addition to the direct savings from recirculating cooling water, an Ontario based manufacturer achieved energy savings of $43,000 per year and was able to indefinitely defer the installation of a new chiller by installing "free cooling." The system reduces energy consumption in cool weather by using atmospheric temperature to reduce the load on the chiller system.

Auxiliary Systems and Facility Equipment:

A large US manufacturer of weather-stripping for automotive applications realized savings of over US $40,000 per year by using natural gas powered chillers.

Environmental Management Systems:

A large US manufacturer reduced waste generation by over 35% despite increasing production volumes. Their highly participative "Pollution Prevention Pays" program was developed as a part of their Total Quality Management initiative.

A large chemical manufacturer achieved over $10,000,000 in savings as a direct result of implementing their EMS resulting in lower energy consumption and reduction of waste.

Emissions Reduction:
A US machine manufacturer achieved total elimination of 19,000 gallons of waste chlorinated solvents by using an alkaline soap solution with a rust inhibiting additive.

A moulder achieved annual savings of $13,000 US by recovering waste hydraulic oil. The implementation cost for the recovery system was $10,000, resulting in a payback period of less than one year.

6. NEW AND EMERGING TECHNOLOGIES

Many facets of plastics processing and related manufacturing technologies evolve continuously. New and modified materials and end use applications are introduced on an ongoing basis. However, unless a new processing technology represents a quick payback on capital investment, it would be expected to penetrate the industry slowly. Despite significant investments in new equipment by many manufacturers in the last few years, a significant portion of machinery in the plastics processing sector is several decades old. This section discusses technologies that are developed, but which have not yet enjoyed full acceptance by the industry.

6.1 Raw Material Developments

The existing variety of plastic raw materials available to the processor is large and yet, still growing. Materials for high volume applications undergo an ongoing development process in an attempt to improve product performance, ease of processing and to reduce cost. Vendors attempt to increase their market shares by replacing competing plastic resins currently in use and by supplanting other materials.

In the last few years, a new family of metallocene catalyzed plastics has been introduced. At this time, they are expensive, scarce and difficult to process. However, the excellent physical properties of these materials are expected to lead to increasing use in applications such as co-extruded packaging for food wrap or as a modifier of other materials as agents that improve clarity.

6.2 Robotics

Robotics are used to improve machine speed, reduce costs, increase safety and to improve quality by maintaining consistent machine cycles.

The most common and simple robotics application is a sprue picker, which is used to ensure positive removal of the sprue from an injection mould. More advanced uses include parts removal and packaging from multiple cavity moulds, especially in applications where products could be damaged by handling, or where maintaining correct orientation of the parts is important.

Another important use of robotics is to place metal inserts into moulds. The accurate positioning of inserts is critical. In some instances, the loading of inserts manually could also pose a safety hazard to the operator.

Some blow moulded applications, pesticide containers for example, require moulded-in labels to ensure that the labels remain in place. Robots are used to place labels into blow moulds during the operating cycle.

6.3 Electric Injection Moulding Machine

Manufacturers have started to produce totally electrically operated injection moulding machines, without hydraulics. Some of the major advertised advantages over conventional machines are:

More efficient use of energy:
Energy savings of over 50% are claimed over conventional hydraulic presses. Motors are sized for the application, fully speed adjustable and only operate when required.

Quiet, clean, compact operation:
Manufacturers claim noise levels in the 73 dB area, versus 78 dB for conventional machines. (A ten decibel reduction is generally perceived as a 50% reduction in noise levels.) This makes the machines quiet enough to operate in an "office" environment. Electric machines also eliminate oil mist problems. The machine footprint is also smaller than conventional machines of an equivalent size.

Better control of process:
More precise and repeatable control results in faster set-ups and better adherence to tolerances. Manufacturers are suggesting that the repeatability and reliability of electric moulding machines will make unattended "lights out" operation a realistic possibility.

Hydraulic oil related issues eliminated:
No need to replace or dispose of hydraulic oil. Also, machine cooling requirements are eliminated.

Faster response time (cycle time):
The reaction time of electrical controls is quicker than electrical/hydraulic units.

The drawback to these units is that they are 20% to 50% more expensive than conventional moulding machines. The differential energy savings are not sufficient to produce a short enough payback for most companies unless quality improvements, lower maintenance, reduced noise and emissions are considered to be important by the purchaser.

There are also hybrid machines available consisting of a hydraulic clamp with electric screw drive and injection.

6.4 Microwave Drying

Microwave drying units dry material using conventional microwave technology and a variety of specific applications are still under development. The main advantage of microwave drying is reduced drying time, allowing more rapid material turnover and lower energy costs. However, the technology is capital intensive and prototype units are batch-oriented while most processes utilize continuous feed systems. Further development will be required to make microwave technology widely accepted for this application.

6.5 Granulators

Manufacturers are developing special rotors or two stage cutters which result in a lower horsepower requirement and lower energy usage for a given throughput.

6.6 Rapid Prototyping

Historically, prototyping of components often necessitated the manufacture of steel moulds. This is both time consuming and costly. Furthermore, design changes often meant that the initial prototype mould had to be extensively modified or scrapped.

In recent years, technologies have been developed to produce prototypes directly from computer designs, without the need for moulds:

> **Stereolithography** is a prototyping process which uses a laser to deposit consecutive thin layers of a polymer in solution. The layers are gradually built up to form a model which may be quite complex in configuration.
>
> **Selective laser sintering** is used to build up layers of material in a manner similar to stereolithography with dry powdered materials, rather than liquid polymers.
>
> **Ballistic particle manufacturing** is a recently developed prototyping method which has adapted a technology similar to ink jet printing. Microscopic particles of molten thermoplastic are "shot" with great accuracy to precise points to build up a three dimensional model.

6.7 Gas-Assisted Injection Moulding

Designers of parts for injection moulding have historically been constrained by the need to maintain relatively constant and thin sections in the finished products. This is because thick wall sections, in addition to requiring a long cooling time, had a tendency to develop sink marks; depressions in the part surface caused by the contraction of the plastic while cooling. Gas-assisted moulding helps to overcome these problems and permits a broader range of applications.

In this process, nitrogen gas is injected into the interior of the melt at the thick sections. The gas pressure creates a hollow area within the plastic and forces the solidifying plastic against the mould. This eliminates sink marks and reduces raw material cost. For certain parts, material savings of up to fifty percent have been reported.

6.8 Co-Injection Moulding

Co-injection moulding provides another method for improving physical properties and/or reducing raw material costs. This process allows for two dissimilar materials to be injected simultaneously through concentric nozzles. The part designer has the latitude to design parts with an outer skin made of a material with the desired visual or physical properties and to inject an internal core with a material which is less expensive, stronger, or lighter.

6.9 Tool Making Technology

Computer Assisted Design and Computer Assisted Manufacturing (CAD/CAM) technologies continue to have an increasing importance in shortening lead times and reducing tooling costs. Digitized information is routinely transmitted from customer to tool vendors and is used directly to guide toolmaking machinery, such as NC milling machines.

Electrical Discharge Machines (EDM) have largely replaced pantographs for making precise tool cavities. Extrusion dies are manufactured using wire cut EDM equipment to produce complex configurations at a lower cost.

Potential exists for an increased use of superior mould alloys to reduce moulding cycles. The majority of tool steels currently in use were developed prior to World War II.

6.10 VOC Control Technologies

There are various technologies available, some of which have been used by fabricators in Ontario for the purpose of reducing VOC emissions and VOC containing materials used in plastics processing operations. The main focus of efforts to date has been in the implementation of processes and work practices leading to reductions in VOC. Some examples of control technologies currently available and/or under development are as follows:

Expanded polystyrene:
Low pentane beads have recently been made available by one company while other companies are still in the research and development stages. At this time, the use of a low pentane bead is likely more suitable for medium and high density products rather than low density products such as insulation board. As well, changes in equipment and processes are necessary in order to use the low pentane bead. Technology and capital cost implications must be considered before this control technology can be utilized widely.

PVC:
The trend in this sector continues to be the development of low VOC plasticizers. Other options include solvent-free stabilizers and low VOC cleaners.

Reinforced plastics/composites (polyester resins):

Reduction options have focused on the use of lower VOC materials and improving process efficiency through equipment changes and good operating practices. Initiatives undertaken to date in the reinforced plastics sector include the use of charcoal filters in stacks to reduce odour and VOC emission levels, reductions in solvent use and the implementation of solvent recycling programs consistent with the CCME guideline. In addition, in house acetone recovery programs have been implemented. Other reductions in VOC emissions can be accomplished by undertaking the following; using low styrene resins, wax suppressed resins and low VOC cleaners, and, through improved process operations and work practices by using high efficiency spray applicators (e.g. airless, high velocity low pressure, electrostatic, flow coaters) and closed moulding technology.

7. BENCHMARKING AND PERFORMANCE MONITORING

Performance ratios are useful in assessing a facility's efforts to reduce energy and water use, and effluent discharges. Establishing a baseline measurement of resource consumption and waste output allows a company to evaluate the improvements made in operations and equipment over time. A series of generic formulae for calculating these ratios is presented here.

For individual pieces of process equipment which are suspected of having significant potential for improvement, it is possible to measure or calculate energy consumption and to develop similar ratios. These can be compared to published data on more efficient equipment and to evaluate and prioritize energy improvement projects.

The following performance ratios calculate both the process and non-process consumption of energy and water use (including utilities devoted to lighting, heating, ventilating and air conditioning). All of these can be calculated directly from the company's utility bills. Any improvements made within a facility should result in a decrease in the ratio.

7.1 Raw Materials Usage

A key benchmark indicator is raw materials usage. Most facilities have the ability to calculate expected or "standard" raw material consumption through the costing system. If the actual consumption, obtained through purchase records, differs significantly from expected consumption, this may be an indication of controllable losses and should be investigated. Often, accurate data is available only after a physical inventory. These "raw material variances" may indicate significant inefficiencies in material handling, scrap rates, set-ups, or the process and may also be used to identify unprofitable products.

As the resin processed in a specified period appears as the denominator in the following calculations, it is important to define usage accurately. Preferably, the kilograms used should be obtained from sales records to avoid counting scrap, purgings or other waste as material "processed."

7.2 Unit Electrical Energy Use

The following formula is suggested for use in computing estimates of "electrical energy use" per unit of plastics material processed at any given facility over any specified time period.

$$\frac{\text{Total kWh electricity consumed over a period} \times 3.6}{\text{Total kg resin processed over the same period}} = \text{Unit Electrical Energy Use in MJ/kg}$$

7.3 Unit Natural Gas Energy Use

The following formula is suggested for use in computing estimates of "natural gas energy use" per unit of plastics material processed at any given facility over any specified time period.

$$\frac{\text{Total cubic meters natural gas used over a period} \times 37.2}{\text{Total kg resin processed over the same period}} = \text{Unit NG Energy Use in MJ/kg}$$

7.4 Unit Water Use

The following formula is suggested for use in computing estimates of "water use" per unit of plastics material processed at any given facility over any specified time period.

$$\frac{\text{Total cubic meters of water used over a period}}{\text{Total kg resin processed over the same period}} = \text{Unit Water Use in } m^3/kg$$

Benchmarking is a valuable tool for comparing performance between and among manufacturing facilities. However, great care must be used to ensure that the data is valid and comparable. For example, in the plastics processing sector, various processes have a wide range of energy requirements. It is often difficult to find precisely identical conditions in other locations and many companies are reluctant to share detailed information with their competitors.

The Plastics Film Manufacturers of Canada and the Canadian Plastics Industry Association (CPIA) are conducting a benchmarking study of Canadian and US manufacturers. Typically, these studies compare 60 financial and operating ratios. Participants are grouped into categories to maintain confidentiality. Each participating firm receives details of competitors' performance to which they can compare their own results. Industry Canada also maintains benchmarking information on their web page at"http://strategis.ic.gc.ca".

Some companies have been successful in obtaining useful information on a reciprocal basis from firms which produce similar or identical products for different geographical markets. Raw material and equipment suppliers may be helpful in facilitating these contacts.

Benchmarking is an important tool for processors interested in the continuous improvement of their processes and facility. Collecting the initial data and determining appropriate ratios is the first step in the improvement process. It defines what parameters are important and how they will be measured; this results in a starting point against which improvements can be compared. Benchmarking focuses the processor on improved performance and gives the organization specific goals to work towards.

8. OTHER HELPFUL INFORMATION

A series of additional reference materials about energy and environmental improvements in plastics reprocessing are described in the following sections. In most cases, contacts are provided for acquiring follow up information.

8.1 Reference Material

Electrical Efficiency Opportunities in the Plastics Processing Industry in Ontario, Canadian Plastics Institute, 1993. This study evaluates the distribution of energy used in various process technologies and identifies energy savings techniques that can be readily adopted, often without major capital expenditures.

Energy Conservation in the Plastics Processing Industry in Canada, Energy, Mines and Resources Canada, 1983. Guidance to processors for establishing successful energy conservation programs, and information on trends in energy use, new and emerging conservation technologies, potential savings and implementation costs.

Energy Efficiency Planning and Management Guide, Canadian Industry Program for Energy Conservation (CIPEC). This useful document describes the methodology for setting up and running an effective energy management program, and provides worksheets for evaluating the energy savings potential from improvements in lighting, electrical systems, boilers, steam and condensate systems, heating and cooling, HVAC, waste heat recovery, etc. For further information, contact the CIPEC secretariat at (416) 798-8155.

Operation Clean Sweep; A manual on Preventing Pellet Loss, The Society of the Plastics Industry, Inc. This manual provides detailed guidance for minimizing raw material losses in the plastics processing industry. The manual covers policies and procedures and recommends a goal of "zero loss of pellets." For further information, contact (202) 974-5200.

Energy Accounting; Energy Mines and Resources, Canada. This series of energy management and technical manuals was prepared to help managers and operating personnel to recognize energy management opportunities. For further information, contact Business and Government Energy Management Division, Energy Conservation Branch, Department of Energy, Mines and Resources, 580 Booth Street, Ottawa, Ontario, K1A 0E4.

Natural Gas Applications for Industry, Volume VII: The Plastics Industry, American Gas Association, 1992. This study examines cost saving opportunities by using gas for a broad range of processing technologies and auxiliary equipment. Operating, technical and cost considerations are discussed and the opportunities are ranked. The document provides useful data and methods for assessing the cost effectiveness of alternative energy inputs.

Plastics Recycling: Products and Processes, Society of Plastics Engineers. A comprehensive survey of the technical, business and environmental components involved in the recycling of plastics (including, PET, polyolefins, polystyrene, polyvinyl chloride, engineering thermoplastics, acrylics, commingled plastics, and thermosets).

8.2 Industry Associations

Canadian Plastics Industry Association (CPIA)
The Canadian Plastics Industry Association is the voice of the plastics industry in Canada. CPIA delivers its services through regional offices and can be a valuable source in the areas of technology, trades, health and safety, and the environment. CPIA - Ontario is located at 365 Bloor Street East, Suite 1900, Toronto, Ontario, M4W 3L4, telephone (416) 323-1883.

Environment and Plastics Industry Council (EPIC)
EPIC was formerly known as the Environment and Plastics Institute of Canada and is now a Council of the Canadian Plastics Industry Association. It provides a wide range of general information about integrated resource management and plastic solid waste issues. Other resources include technical reports and information for solid waste managers about plastics recycling collection and sortation methods. EPIC can be reached in Toronto at (905) 678-7748.

Society of Plastics Engineers (SPE)
The objective of the SPE is to "promote the scientific and engineering knowledge related to plastics." This association holds an annual technical conference (ANTEC), which attracts a wide audience interested in all technical aspects of the plastics industry. For information, contact (203) 775-0471.

8.3 Industry Directories and Guides

Environment and Plastics Institute of Canada, 1995. ***Plastics Recycling Directory***. Provides a listing and cross indexing of the participants in all aspects of plastics recycling in Canada including processors, equipment suppliers, services and associations. Available from EPIC at (905) 678-7748.

Ontario Ministry of Environment and Energy, 1996. ***Directory of Ontario Green Industries***. This directory provides a listing and description of over 2,000 Ontario suppliers of pollution prevention, pollution control and remediation equipment. The index is cross referenced by environmental specialty. Contact the MOEE Public Information Centre for copies at 1-800-565-4923 or (416) 325-4000.

Industrial Gas Technology Commercialization Center, 1996. ***Natural Gas Plastic/Polymer Process Equipment Guide***. Discusses the applications of new natural gas equipment for air compressors, central thermal fluid systems, desiccant air dryers and resin dryers. Available from the Industrial Center at (703) 841-8463.

NRCan, 1994. ***CEMET Resource Catalogue.*** List and description of available energy efficient products and services. For information, contact NRCan at (613) 995-6839.

NRCan, 1997. ***Tips for Energy Managers, Toolkit for Your Employee Awareness Program.*** For information, contact NRCan at (613) 995-6839.

McGraw-Hill, annual. ***Modern Plastics Encyclopedia.*** Annual publication with a wealth of information about plastic materials, technologies, industry trends and process descriptions. For information, contact (609) 426-5129.

Ontario Hydro, ***Reference Guides.*** Ontario Hydro has published a series of energy guides covering adjustable speed drives, lighting, power quality and other topics. For information, contact any Ontario Hydro Energy Services field office.

Ontario Hydro, ***Powersaver Options.*** Case studies in energy management including a "free cooling" installation in the plastics processing industry which resulted in annual savings of $43,000. For information, contact any Ontario Hydro Energy Services field office.

8.4 Environmental/Resource Audit Guidance Documents

Harmony Foundation of Canada, 1991. ***Workplace Guide - Practical Action for the Environment.*** This guide was developed to introduce methods for implementing environmentally sustainable practices in industry. It describes tools to be used by organizations to assess environmental strengths and weaknesses, develop a strategic plan and implement improved environmental practices, including resource conservation. It offers a comprehensive step-by-step approach to help identify both economic and environmental benefits through positive thinking, serious commitment and co-operative action. Copies may be obtained from the Harmony Foundation of Canada, 1183 Fort Street, Victoria, British Columbia, V8V 3LT. Telephone: (250) 380-3001, fax: (250) 380-0887, email: harmony@islandnet.com.

National Round Table on the Environment and Economy, 1991. ***Decision Making Practices for Sustainable Development.*** This book provides a template for organizations implementing environmental management strategies. Assistance in making critical corporate environmental choices and decisions by providing effective checklists such as the Business Code of Practice Strategy Checklist for decision makers who want to incorporate sustainable development considerations in their organizational decisions. Procter & Gamble Inc.'s experience in developing their corporate environmental strategy is provided as a case study. Copies may be obtained from the National Round Table on the Environment and the Economy, 1 Nicholas Street, Suite 1500, Ottawa, Ontario, K1N 7B7. Telephone (613) 992-7189.

Natural Resources Canada, Efficiency and Alternative Energy Program. ***A Manager's Guide to Creating Awareness of Energy Efficiency***. Provides an outline of a program for communicating and involving employees in energy management programs in the workplace. The document includes a disk of prepared communications articles and graphics. Copies may be obtained from Natural Resources Canada at (613) 995-6839.

Natural Resources Canada, Efficiency and Alternative Energy Program, 1994. ***Technical Information***. The information is a technical bibliography and a compendium of technical fact sheets on topics relating to energy conservation in buildings. Copies may be obtained from Natural Resources Canada at (613) 995-6839.

8.5 Pollution Prevention Guidance Documents

Ontario Ministry of Environment and Energy, 1993. ***Pollution Prevention Planning: Guidance Document and Workbook***. PIBS 2586E. ISBN 0-7778-1441-2. The workbook introduces pollution prevention planning and implementation concepts and principles; offers a model/approach to initiating team planning exercises and provides worksheets and checklists for implementation. Contact the MOEE Public Information Centre for copies at 1-800-565-4923 or (416) 325-4000.

Canadian Standards Associations, 1994. ***Guideline for Pollution Prevention Z754-94***. Call toll free to order 1-800-463-6727.

Canadian Council of Ministers of the Environment (CCME), 1996. ***Environmental Guideline for the Reduction of Volatile Organic Compound Emissions From the Plastics Processing Industry.*** This guideline contains raw material, equipment, process and operating standards for plastics processing facilities. Call (204) 945-1576.

8.6 Environmental Management Systems

Alliance of Manufacturers and Exporters. ***ISO 14000 - Essential Steps Towards an Internationally Recognized Environmental Management System.*** Describes the ISO 14000 infrastructure and answers frequently asked questions about the assessment, implementation and registration processes. It includes a list of ISO 14000 consultants and registrars.

Alliance of Manufacturers and Exporters. ***ISO 14000 - Environmental Management System Assessor Checklist and Proforma Consultant's Report.*** This publication is for use by companies seeking compliance with the ISO 14001 standard.

8.7 Web Sites

Many manufacturers, government agencies, research organizations, utilities and industry associations have web sites. Some of these sites include:

Ministry of Environment:

www.ene.gov.on.ca

Canadian Plastics Industry Association:

http://www.plastics.ca

This is the official web site of the Associations and provides various information and contacts throughout industry.

The Environmental Industry Virtual Office:

http://VirtualOffice.ic.ca/on

This web site is a public-private sector partnership which is intended to promote and facilitate the growth and development of the environmental industry by providing quick and easy access to major providers or sources of information, services and advice on Research and Development, Domestic and International Markets, Investment and Financing, and Human Resources.

The Canadian Environmental Performance Office (CBEPO):

http://VirtualOffice.ic.gc.ca/CBEPO

This is a Federal, Ontario Government and private sector pilot project which, when complete, will become a source of environmental performance reference materials for Ontario based manufacturers industry. Specific attention will be given to information about the plastics sector.

Other Web Sites

Numerous web sites offer information and case studies on environmental issues. Some such sites are listed in Appendix V.

8.8 Environmental Approvals and Certificates

Ontario Ministry of Environment (MOE) Approvals Branch, 1995. ***Approvals Functions.*** A guide to applying for Certificates of Approval to operate facilities. Available from any Ministry Regional or District Offices listed in the blue pages of the telephone book.

Ontario Ministry of Environment (MOE) Approvals Branch, 1994. ***Guide for Applying for Approval (Air).*** Equipment or processes which may discharge a contaminant into the atmosphere may require a Certificate of Approval under Section 9 of the Environmental Protection Act. This guide will assist owners to file the required applications.

Ontario Ministry of Environment (MOE) Approvals Branch, 1994. ***Guide for Applying for Approval of Industrial Sewage Works.*** This guide will assist companies who are planning to install sewage treatment facilities to obtain the permits required under Section 53 of the Ontario Water Resources Act.

ACRONYMS

- ABS - acrylonitrile butadiene styrene
- AC - alternating current
- BDC - brushless direct current
- CPI - formerly Canadian Plastics Institute, now Canadian Plastics Industry Association
- CPIA - Canadian Plastics Industry Association
- CPRA - Canadian Polystyrene Recycling Association
- DC - direct current
- EPA - Environmental Protection Act
- EPIC - formerly Environment and Plastics Institute of Canada, now Environment and Plastics Industry Council
- EPS - expanded polystyrene
- GPP - general purpose polystyrene
- HE - high efficiency
- HDPE - high density polyethylene
- HP - horsepower
- HVAC - heating, ventilation and air conditioning
- IC&I - industrial, commercial and institutional
- JIT - just in time
- LDPE - low density polyethylene
- LLDPE - linear low density polyethylene
- MOE - Ministry of the Environment
- PC - polycarbonate
- PE - polyethylene
- PET - polyethylene terephthalate
- PP - polypropylene
- PS - polystyrene
- PVC - polyvinyl chloride
- 3Rs - reduce, reuse and recycle
- RCO - Recycling Council of Ontario
- SPI - Society of the Plastics Industry of Canada, now CPIA
- VSD - variable speed drive

GLOSSARY

Band Heater
Electrical resistance heater which encircles the screw barrel to provide supplementary heating and temperature control.

Barrel
Cylinder which houses the screw in an extrusion or moulding process.

Blender
A unit to mix and meter resins and/or additives in desired proportions.

Blow moulding
A process which uses compressed air to inflate a hollow tube of plastic inside a mould.

Blown film extrusion
A process which uses air to inflate and cool a "bubble" of plastic into a thin film. Typically used for manufacturing plastic bags.

Captive processor
A manufacturing operation which produces plastic products for internal use, rather than for sale.

Cartridge heater
A tubular heater, often inserted into a mould to provide controlled heating.

Chiller
A unit designed to circulate a coolant (often water) to process equipment.

Coextrusion
The process of extruding two or more different resins at the same time into a single end product.

Contaminant
Foreign materials (such as dirt, metals, incompatible resins, organic waste, oil or the residues of the contents of plastic containers) which make plastic materials more difficult to process and cause quality problems in finished products.

Custom Processor
Manufacturing operation which produces products for sale to a variety of customers.

Degradable Plastics
Plastics specifically developed or formulated to break down after exposure to sunlight or microbes. Complete degradation has not been achieved at current levels of development.

Die
A metal plate through which molten material is forced. A precisely designed and cut profile in the die forces the molten plastic to assume a desired shape and to begin the cooling process.

Energy Recovery
A process that extracts energy value from a substance such as air, water or solid waste and transfers it to another medium to be used again. Examples are heat recovery from exhaust streams to preheat incoming air or the burning of solid waste as fuel to generate heat.

Extrudate
Material which has been forced through a die in an extrusion process.

Extrusion
The process of forcing molten plastic through a die to produce continuous lengths of material with a desired profile.

Fillers
An inert substance added to plastic to reduce cost, or to improve physical properties.

Foaming agents
Chemicals added to plastics and rubbers which generate gases during processing and produce a cellular structure.

Grinding
The process of reducing plastic components into smaller particles suitable for feeding into a process.

Injection moulding
A plastics manufacturing process which injects molten material into a closed mould under high pressure.

Injection blow moulding
A plastics manufacturing process which combines injection and blow moulding. An injection moulded preform is transferred to a blow moulding station for processing into the final configuration.

Just in Time (JIT)
A manufacturing philosophy designed to reduce inventories, lead times and improve quality by reducing set-up times and manufacturing work in process.

Monomers
The basic chemical building blocks used to create plastic polymers (long chain molecules).

Mould
A two part unit into which material is introduced and which is configured to produce a desired shape. The mould is often cooled to speed up the solidification of the molten material. After solidification, the mould is opened to remove the finished part.

Multi-cavity
Refers to a mould with more than one cavity. For high volume production, moulds with more than one hundred cavities are common.

Off-Spec Resin
Any resin that does not meet its manufacturer's specifications, but may still be offered for sale.

Ontario Regulation 347
Waste Management — General Regulation 347, under Ontario's Environmental Protection Act, sets out standards for solid waste disposal sites and waste management systems, and governs the handling, transport and disposal of registerable liquid industrial and hazardous wastes.

Parison
A round hollow tube of semi-molten plastic which is extruded and goes on to be further processed in a blow moulding machine.

Payback
Payback (simple payback) is the ratio of the annualized savings from a process or machinery improvement divided by the capital and installation cost of the improvement project.

Pellet
A small piece of plastic resin, suitable for feeding into a process.

Plastics
Synthetic materials consisting of large polymer molecules derived from petrochemicals or renewable sources. Plastics are capable of being shaped or moulded under the influence of heat, pressure or chemical catalysts. Polymer resins are often combined with other ingredients including colourants, fillers, reinforcing agents and plasticizers, to form plastic products.

Polymer
A very long chain molecule built up by repetition of small chemical units known as monomers, strongly bonded together.

Preform
An injection moulded intermediate product which is inserted into a blow moulding machine.

Process
Aspects of a manufacturing operation, such as moulding or extrusion, which are directly related to the physical transformation of the material.

Properties
The physical characteristics of materials which may be used to differentiate plastics among themselves and other materials.

Reinforced plastics
Plastic materials which have reinforcing materials added to them such as glass fibers or mats.

Resin
A synonym for "polymer".

Screw
A shaft with flights, confined within a barrel, which conveys material from a hopper to a die or a mould. The material is plasticized during this process through a combination of mechanical "shear" heating and external heat provided by band heaters around the barrel.

Shot
A precise amount of molten plastic material introduced into a mould during the injection moulding process.

Sheet moulding compound
A ready to mould fiberglass reinforced polyester material used for compression moulding.

Strip heater
A flat electric resistance heater.

Thermoplastics
Plastic resins that can be repeatedly softened by heating, shaped by flow into articles by moulding or extrusion, and hardened.

Thermosets
Plastic resins that are hardened or "cured" by an irreversible chemical reaction which creates strong cross-links between the polymer molecules. Once formed, thermosets cannot be remelted without degrading the resin.

Three Rs (3Rs)
The reduction, reuse and recycling of waste.

Virgin Materials
Any raw material intended for industrial processing which has not been previously used.

APPENDIX I - ENERGY AUDIT HIGHLIGHTS FROM ONTARIO PLASTICS PROCESSORS

Energy audits were undertaken at 67 Ontario plastic processing facilities between 1987 and 1995 under the Industry Energy Services Program (IESP) of the Ministry of Environment and Energy. Figures A-1 and A-2 are illustrations of the potential savings that exist for a variety of improvements that were considered as part of these energy audits. The energy audits data has been aggregated and as such are intended simply to point towards potential savings opportunities that should be considered for further review when examining specific plastics processing operations.

The IESP energy analysis reports identified four energy conservation technologies with widespread opportunities in the plastics sector; 1) heat recovery, 2) operations modification, 3) HVAC and ventilation and 4) lighting. For each of these four technologies, the total number of opportunities identified is located along the bottom scale of Figure A-1. Estimates of the total capital cost of each of these opportunities is indicated by the left bar, and the annual cost savings from these opportunities is indicated by the right bar.

IESP energy analysis reports for the plastics processing sector identified energy conservation technologies associated with heat recovery as having significant savings potential. Three important sources of heat recovery considered include; 1) exhaust air, 2) process effluent and 3) compressed air. For each type of heat recovery, the number of opportunities identified is indicated in brackets along the bottom scale. The total capital cost of these opportunities is indicated along the left bar of Figure A-2, and the total annual cost savings from these opportunities is indicated by the right bar.

Figure A-1: Estimated Capital Cost and Annual Savaings Associated with Energy Improvements at Ontario Plastics Processing Plants

(Based on IESP energy analysis reports for 67 Ontario plastic processing plants)

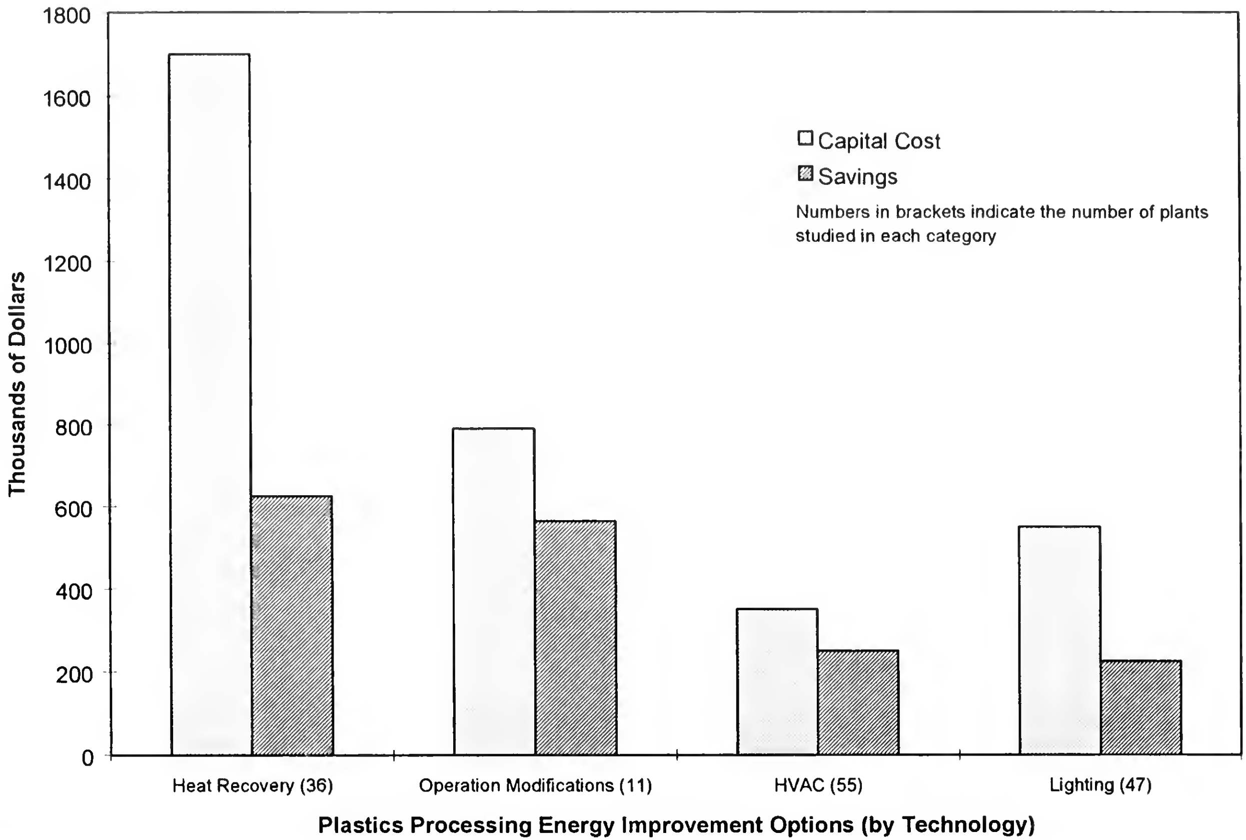
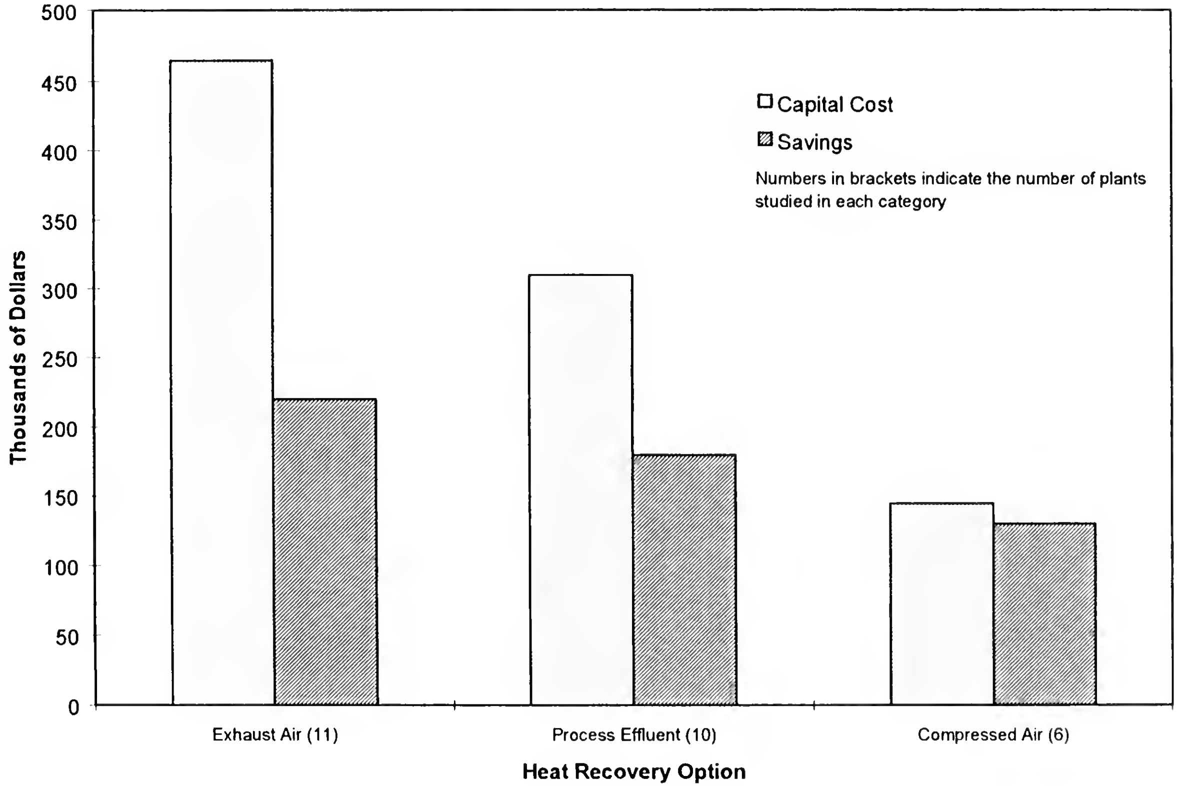


Figure A-2: Estimated Capital Cost and Annual Savings Associated with Improvements in Ontario Plastic Processing Plant Heat Recovery
(Based on IESP energy analysis reports for 67 Ontario plastic processing plants



APPENDIX II - ISO 14000 STANDARD SERIES

ISO 14000 STANDARD SERIES

NUMBER	STANDARD TITLE
14001	EMS - Specification With Guidance for Use
14004	EMS - General Guidelines on Principles, Systems and Supporting Techniques
14010	EA - General Principles of Environmental Auditing
14011.1	EA - Audit Procedure Part 1: Auditing of EMS
14012	EA - Qualification Criteria for Environmental Auditors
14014	EA - Initial Reviews
14015	EA - Environmental Site Assessments
14020	EL - General Principles
14021	EL - Self-Declaration, Environmental Claims, Terms and Definitions
14022	EL - Self-Declaration, Environmental Claims, Symbols
14023	EL - Self-Declaration, Environmental Claims - Testing and Verification Methodologies
14024	EL - Practitioner Programs: General Principles, Practices and Certification Procedures of Multiple Criteria Programs.
14025	Type III Environmental Labelling
14031	Environmental Performance Evaluation
14040	LCA - General Principles and Guidelines
14041	LCA - Inventory Analysis
14042	LCA - Impact Assessment
14043	LCA - Interpretation
14050	Terms and Definitions
14060	Guide for the Inclusion of Environmental Aspects in Product Standards

EMS - Environmental Management System

EL - Environmental Labels and Declarations

EA - Environmental Auditing

LCA - Life Cycle Assessment

APPENDIX III SCOPE OF GENERIC PLASTIC MANUFACTURING PROCESSES USED IN CANADA

Process	Major resins used
Film extrusion	PE, PP, PS, Nylon
Injection moulding	PP, PVC, PS, ABS, PET, Nylon, Acrylic
Profile extrusion	PE, PVC, PS, ABS, Nylon
Sheet extrusion	PVC, PE, PS, ABS, PP, Acrylic
Foam extrusion	PS, PE, Phenolic
Calendared sheet extrusion	PVC, PS, PE, Acrylic, ABS
Plastisol processing	PVC
Rotational moulding	PE, PP
Blow moulding	PE, PP, PET, PVC
Lamination, film	PE, Nylon. PET
Lamination, thermoset	Phenolic, Urethane, Polyester
Compression moulding	Phenolic, U-F, M-F
Spray/pour	Urethanes
Open moulding	Urethanes, Phenolic, U-F
Filament winding	Polyester, Epoxy
Pultrusion	Polyester, Epoxy
Matched die moulding	Urethanes, Polyester, Phenolic

Source: Law, Sigurdson and Associates, 1993

APPENDIX IV -SELECTED ENERGY EFFICIENCY OPPORTUNITIES IN THE PLASTICS PROCESSING SECTOR

Injection moulding, extrusion and blow moulding operations were examined in 1993 by Power Smart, Inc. for Energy, Mines and Resources, Canada. Portions of this study were published by the Canadian Plastic Institute (CPI) under the Canadian Industry Program for Energy Conservation (CIPEC). Process specific summaries of energy efficiency opportunities from this initiative are reproduced below.

Canadian Industry Program for Energy Conservation

CIPEC

ENERGY EFFICIENCY OPPORTUNITIES IN THE PLASTICS INDUSTRY

Canadian
Plastics
Institute

1.0 ENERGY SAVINGS - INJECTION MOULDING

Energy saving opportunities in injection moulding are focused on the moulding machine. In all cases the machine design affects the energy efficiency. In many operations, over 50% of the electrical energy used is consumed by the moulding machine. In addition energy savings opportunities can be applied to mould and machine cooling and to other auxiliary systems.

The Injection Moulding Machine

The Injection Moulding Machine	The Energy Saving Technique	Potential Saving %
Mould close, transport and clamping	Variable hydraulic power to match load requirements. Can be achieved by using variable speed drives, variable displacement pumps, accumulators and control system.	45
Extruder barrel heating	Insulate extruder barrel with fiber glass blanket or use insulated heaters.	30
Extruder drive systems	Change SCR or vane type hydraulic drive system to variable speed AC or brushless DC drives.	20
Machine control systems	Change old controls (timers etc) to PLC or computerized systems. (Will increase productivity by up to 10%)	0
Centralized hydraulic system	Arrange for one central hydraulic power system to supply a group of similar injection moulding machines.	50
Alternative energy source	Change to natural gas driven equipment. e.g. industrial IC engines, co-generation, absorbtion chillers, driers etc.	70

Injection Moulding Machine - Auxiliary Equipment

The Injection Moulding Machine Auxiliary Equipment	Energy Saving Technique	Potential Saving
Material driers (electric)	Use "high efficiency" electrically powered driers.	30
Material driers (natural gas)	Use "high efficiency" gas fired driers for high volume drying operation. (Typical for PET moulding)	70
Dew point monitoring of driers	Install dew point monitoring system on material driers.	20
"Free Cooling" systems	Use cooling tower water with heat exchanger for mould cooling in winter months.	40
Variable speed cooling water pumps	Control pump speed to match output required rather than throttling the pump.	30
Variable speed cooling tower fans	Control cooling tower fan speed to cooling level required.	20
Variable speed chiller compressor	Control speed of chiller compressor to match cooling load, eliminating the need for artificial load. (hot gas bypass)	25
Compressed air system	Ensure system is correctly sized for the load, well managed and if of sufficient capacity, stage the compressors.	20

1.2 INJECTION MOULDING - Potential Energy Saving by Plant

Equipment and Systems	Energy Dist. %	Energy Saving Technique	Typical Energy Saving %	Energy Saving by Plant %	Capital High, Medium, Low.
Mould close, trans. and clamping	36	Variable power hydraulic system to match load	45	16.2	M
Extruder barrel heating	19	Barrel insulation - fiber glass blanket	30	5.7	L
Extruder drive system	18	Change SCR or vane type hydraulic to high efficiency brushless DC or variable frequency AC	20	3.6	L
Machine control system	0	Change to PLC or computer based control system. Will improve overall output. (Usually increase output by 10%)	0	0	M
Central hydraulic system	36	Central hydraulic system operating a group of similar injection moulding machines.	50	18.0	H
Material Driers (low capacity electric)	7	Use "high efficiency" electric driers	30	2.1	L
Material Driers (high capacity Nat.gas)	7	Use "high efficiency", large capacity, gas fired driers	70	4.9	M
Material Driers (all driers)	7	Install "dew point" monitoring and control system	20	1.4	L
Mould and Machine cooling (chillers)	4	Use cooling tower with heat exchanger for mould cooling in winter months. ("Free Cooling")	40	1.6	H
Mould and Machine cooling (pumps)	1.5	Use variable speed pumps to control output	30	0.5	L
Mould and M/C cooling (tower fan)	0.5	Use variable speed tower fan	20	0.1	L
Mould and Machine cooling (chillers)	4	Use variable speed chiller compressors	25	1.0	M
Compressed air system	2	Correctly sized, well managed and "staged"	20	0.4	L
Alternative energy source	80	Use natural gas powered equipment - IC engines, absorption chillers etc. (This will reduce energy costs, not energy used.	70	56	VH

1.3 INJECTION MOULDING - Estimated cost savings available

The cost savings available will be dependent upon the energy requirements of the specific plants. For convenience, a range of energy requirements has been selected and from these, the annual energy costs have been calculated. This is based on an energy charge of $0.06/kWh and a plant operation of 24 hours/day, 7 days/week and 50 weeks/year.

		Plant Energy Level 200kW	Plant Energy Level 500kW	Plant Energy Level 1,000kW	Plant Energy Level 2,000kW	Plant Energy Level 3,000kW
Annual Energy Cost, 8,400 hrs/yr @ $0.06/Kwh (000)		$100.8	$252.0	$504.0	$1,008	$1,512
Equipment and System Modifications	Plant Energy Savings %	Savings in Energy Costs $	Savings in Energy Costs $	Savings in Energy Costs $	Savings in Energy Costs $	Savings in Energy Costs $
Variable hydraulic power to mould clamp/transport	16.2	16,200	40,800	81,600	163,300	245,000
Insulate extruder barrels	5.7	5,800	14,400	28,700	57,500	86,200
Upgrade inefficient extruder drive systems	3.6	3,600	9,100	18,100	36,300	54,400
Central Hydraulic system for mould clamp/transport	18.0	18,100	45,400	90,700	181,400	272,200
"High efficiency" (electric) material driers	2.1	2,100	5,300	10,600	21,200	31,800
"High efficiency" (natural gas) material driers	4.9	4,900	12,300	24,700	49,400	74,100
Dew point monitoring & control for all driers	1.4	1,400	3,500	7,000	14,100	21,200
Mould cooling with tower water ("free cooling")	1.6	1,600	4,000	8,100	16,100	24,200
Variable speed cooling water pumps	0.5	500	1,300	2,500	5,000	7,500
Variable speed cooling tower fans	0.1	100	250	500	1,000	1,500
Variable speed chiller compressors	1.0	1,000	2,500	5,000	10,000	15,000
Correctly sized and managed compressed air system	0.4	400	1,000	2,000	4,000	6,000
Use natural gas as an alternative fuel (IC engines for generating electricity, absorption chillers etc.)	56.0	56,400	141,100	282,200	564,500	864,700

2.0 ENERGY SAVINGS - EXTRUSION

Energy saving opportunities in extrusion are focused mainly on auxiliary systems. Some savings are also available on the extruder and haul off equipment. Most profile, pipe, sheet and blown film operations process large quantities of material and cooling systems offer an excellent opportunity for energy saving.

The Extruder

The Extruder	The Energy Saving Technique	Potential Saving %
Extruder barrel heating	Insulate extruder barrel with fiber glass blanket or insulated band heaters.	15
Extruder drive system	Investigate speed range with respect to motor size. SCR drives are inefficient below 70-80% rated speed. If this is so, change to high efficiency variable speed drive system. e.g. brushless DC or variable frequency AC drive. Size to suit output required.	20
Alternative energy source	Consider natural gas driven equipment. Change SCR or vane type hydraulic drive system to variable speed AC or brushless DC drives.	70

Extrusion - Auxiliary Equipment

Extrusion Auxiliary Equipment	Energy Saving Technique	Potential Saving
Material driers (electrical)	Use "high efficiency" electrically powered driers.	30
Material driers (natural gas)	Use gas fired driers for high volume application. (Typical for PET)	70
Dew point monitoring of driers	Install dew point monitoring and control system.	20
"Free Cooling", systems	Use cooling tower water with heat exchanger for mould cooling in winter months.	40
Variable speed cooling water pumps	Control pump speed to match output required rather than throttling the pump.	30
Variable speed cooling tower fans	Control cooling tower fan speed to match cooling level required rather than switching motors on and off	20
Variable speed chiller compressor	Control speed of chiller compressor to match cooling load, eliminating need for artificial load. (hot gas bypass)	25
Air compressor operation	Ensure the system is correctly sized, well managed and if of sufficient capacity, stage the compressors.	20

2.2 EXTRUSION - Potential Energy Saving by Plant

Equipment and Systems	Energy Dist. %	Energy Saving Technique	Typical Energy Saving %	Energy Saving by Plant %	Capital High, Medium, Low.
Extruder barrel heating	7	Barrel insulation - fiber glass blanket	15	1.1	L
Extruder drive system	41	Change SCR to high efficiency brushless DC or variable frequency AC (high eff. at low speed)	20	8.2	M
Material Driers (low capacity electric)	7	Use "high efficiency" electric driers	30	2.1	L
Material Driers (high capacity Nat.gas)	7	Use "high efficiency" large capacity gas fired driers	70	4.9	M
Material Driers (all driers)	7	Install dew point monitoring and control system	20	1.4	L
Mould and Machine cooling (chillers)	14	Use cooling tower with heat exchanger for mould cooling in winter months.	40	5.6	H
Mould and Machine cooling (pumps)	6	Use variable speed pumps to control output	30	1.8	L
Mould and M/C cooling (tower fan)	3	Use variable speed tower fan	20	0.6	L
Mould and Machine cooling (chillers)	14	Use variable speed chiller compressors	25	3.5	M
Compressed air system	3	Correctly sized, well managed and "staged"	20	0.6	L
Alternative energy source	85	Use natural gas powered equipment - IC engines, absorption chillers etc. (This will reduce energy costs, not energy used.)	70	59.5	VH

2.3 EXTRUSION - Estimated cost savings available

The cost savings available will be dependent upon the energy requirements of the specific plants. For convenience, a range of energy requirements has been selected and from these, the annual energy costs have been calculated. This is based on an energy charge of $0.06/Kwh and a plant operation of 24 hours/day, 7 days/week and 50 weeks/year.

		Plant Energy Level 200kW	Plant Energy Level 500kW	Plant Energy Level 1,000kW	Plant Energy Level 2,000kW	Plant Energy Level 3,000kW
Annual Energy Cost, 8,400 hrs/yr @ $0.06/Kwh (000)		$100.8	$252.0	$504.0	$1,008	$1,512
Equipment and System Modifications	Plant Energy Savings %	Savings In Energy Costs $	Savings in Energy Costs $	Savings in Energy Costs $	Savings in Energy Costs $	Savings in Energy Costs $
Insulate extruder barrels	1.1	1,100	2,800	5,500	11,100	16,600
Upgrade inefficient extruder drive systems	8.2	8,300	20,700	41,300	82,700	124,000
"High efficiency" (electric) material driers	2.1	2,100	5,300	10,600	21,200	31,800
"High efficiency" (natural gas) material driers	4.9	4,900	12,300	24,700	49,400	74,100
Dew point monitoring & control for all driers	1.4	1,400	3,500	7,000	14,100	21,200
Mould cooling with tower water ("free cooling")	5.6	5,600	14,100	28,200	56,400	84,700
Variable speed cooling water pumps	1.8	1,800	4,500	9,100	18,100	27,200
Variable speed cooling tower fans	0.6	600	1,500	3,000	6,000	9,100
Variable speed chiller compressors	3.5	3,500	8,800	17,600	35,300	52,900
Correctly sized and managed compressed air system	0.6	600	1,500	3,000	6,000	9,100
Use natural gas as an alternative fuel (IC engines for generating electricity, absorption chillers etc.)	59.5	60,000	150,000	300,000	600,000	900,000

3.0 ENERGY SAVINGS - BLOW MOULDING

Blow moulding includes extrusion blow, injection and injection stretch blow moulding. Energy saving opportunities are centred less on the machine and more on the auxiliary equipment. Machine clamping forces are lower and hydraulic requirements are less thus limiting the energy savings as compared with injection machinery. Other energy savings are centred on the compressed air systems which is an integral part of the process, together with mould and machinery cooling.

The Blow Moulding Machine

The Blow Moulding Machine	The Energy Saving Technique	Potential Saving
Extruder barrel heating	Insulate extruder barrel with fiber glass blanket or use insulated heaters.	30
Extruder drive systems	Change SCR DC, to variable frequency AC or brushless DC drives. (Will also improve speed control on multiple extruder machines	20
Machine control systems	Change old controls (timers etc) to PLC or computerized systems. Will usually increase productivity by approx. 10%)	0
Centralized hydraulic system	Arrange for one central hydraulic power system to supply a group of similar blow moulding machines. Also centralize hydraulic system for parison programmers.	30
Alternative energy source	Change to natural gas driven equipment. e.g. industrial IC engines, co-generation, absorbtion chillers, driers etc.	70

Blow Moulding Machine - Auxiliary Equipment

Blow Moulding Machine Auxiliary Equipment	Energy Saving Technique	Potential Saving
Compressed air system operation	Ensure system is correctly sized, well maintained and that compressors are "staged".	20
Multiple compressed air systems	Use separate compressed air systems for plant use (100 psi) and blow operation (up to 150 psi exrtusion blow and up to 750 psi for injection blow.)	25
Material Driers (electrical)	Use "high efficiency" electrically powered driers.	30
Material Driers (Natural gas)	Use natural gas fired driers for high volume application. (Typical PET in injection and injection stretch operations)	70
Dew point monitoring of driers	Install dew point monitoring system on material driers.	20
"Free Cooling" systems	Use cooling tower water with heat exchanger for mould cooling in winter months.	15
Variable speed cooling water pumps	Control pump speed to match output required rather than throttling the pump.	30
Variable speed cooling tower fans	Control cooling tower fan speed to cooling level required.	15
Variable speed chiller compressor	Control speed of chiller compressor to match cooling load, eliminating the need for artificial load. (hot gas bypass)	25

3.2 BLOW MOULDING - Potential Energy Saving by Plant

Equipment and Systems	Energy Dist. %	Energy Saving Technique	Typical Energy Saving %	Energy Saving by Plant %	Capital High, Medium, Low.
Extruder barrel heating	13	Barrel insulation - fiber glass blanket	30	3.9	L
Extruder drive system	26	Change SCR to high efficiency brushless DC or variable frequency AC (high eff. at low speed)	20	5.2	M
Machine control system	0	Change to PLC or computer based control system. Will improve overall output. (usually increase output by 10%)	0	0	M
Central hydraulic system	11	Central hydraulic system operating a group of machines including parison programming.	30	3.3	H
Compressed air system	17	Correctly sized, well managed and "staged"	20	3.4	L
Multiple compressed air systems	17	Use separate HP (blow) and LP (plant) air systems	25	4.3	H
Material Driers (low capacity electric)	4	Use "high efficiency" electric driers	30	1.2	L
Material Driers (high capacity Nat.gas)	4	Use "high eff." large capacity gas fired driers	70	2.8	M
Material Driers (all driers)	4	Install "dew point" monitoring and control system	20	0.8	L
Mould and Machine cooling (chillers)	6	Use cooling tower with heat exchanger for mould cooling in winter months. ("free cooling")	40	2.4	H
Mould and Machine cooling (pumps)	2	Use variable speed pumps to control output	30	0.6	L
Mould and M/C cooling (tower fan)	1	Use variable speed tower fan	20	0.2	L
Mould and Machine cooling (chillers)	6	Use variable speed chiller compressors	25	1.5	M
Alternative energy source	80	Use natural gas powered equipment - IC engines, absorption chillers etc. (This will reduce energy costs not energy used.)	70	56	VH

3.3 BLOW MOULDING - Estimated cost savings available

The cost savings available will be dependent upon the energy requirements of the specific plants. For convenience, a range of energy requirements has been selected and from these, the annual energy costs have been calculated. This is based on an energy charge of $0.06/Kwh and a plant operation of 24 hours/day, 7 days/week and 50 weeks/year.

		Plant Energy Level 200kW	Plant Energy Level 500kW	Plant Energy Level 1,000kW	Plant Energy Level 2,000kW	Plant Energy Level 3,000kW
Annual Energy Cost, 8,400 hrs/yr @ $0.06/Kwh (000)		$100.8	$252.0	$504.0	$1,008	$1,512
Equipment and System Modifications	Plant Energy Savings %	Savings in Energy Costs $	Savings in Energy Costs $	Savings in Energy Costs $	Savings in Energy Costs $	Savings in Energy Costs $
Insulate extruder barrels	3.9	3,900	9,800	19,600	39,300	59,000
Upgrade inefficient extruder drive systems	5.2	5,200	13,100	26,200	52,400	78,600
Central Hydraulic system for mould clamp/transport	3.3	3,300	8,300	16,600	33,300	49,900
Correctly sized and managed compressed air system	3.4	3,400	8,600	17,100	34,300	51,400
Separate compressed air systems for plant and blow	4.3	4,300	10,800	21,700	43,300	65,000
"High efficiency" (electric) material driers	1.2	1,200	3,000	6,000	12,000	18,100
"High efficiency" (natural gas) material driers	2.8	2,800	7,100	14,100	28,200	42,300
Dew point monitoring & control for all driers	0.8	800	2,000	4,000	8,000	12,100
Mould cooling with tower water ("free cooling")	2.4	2,400	6,000	12,100	24,200	36,300
Variable speed cooling water pumps	0.6	600	1,500	3,000	6,000	9,100
Variable speed cooling tower fans	0.2	200	500	1,000	2,000	3,000
Variable speed chiller compressors	1.5	1,500	3,800	7,600	15,100	22,700
Use natural gas as an alternative fuel (IC engines for generating electricity, absorption chillers etc.)	56.0	56,400	141,100	282,200	564,500	864,700

APPENDIX V - SELECTED CASE STUDIES FROM THE PLASTICS PROCESSING SECTOR

CASE STUDY TITLE	SOURCE
MnTAP Case Study: Plastics Manufacturer Reduces Waste Through Good Housekeeping and Recycling	EnviroSense - US EPA web site http://es.inel.gov/studies
Energy Audits of Ontario Plastics Processors	MOEE - See Appendix I
Energy Efficiency Opportunities in the Plastics Industry	CIPEC/CPI/Power Smart Inc. - See Appendix IV
Installation of "Free Cooling" Systems	Ontario Hydro, POWERSAVER OPTIONS, Case Study No. 23
Nishikawa Standard saves $40,000 yearly	Gas Technology, American Gas Association Tel: (703) 841-8569
Case Study: Van Dorn Plastics Machinery - Strongsville	EnviroSense - US EPA web site http://es.inel.gov/techinfo/case/comm/vandorn.html
Dow Chemical Co: $10 mm in Savings, Energy and Waste	http://www.wri.org/wri/meb/pub.html
Pollution Prevention Pays: 3M Co.	EnviroSense - US EPA web site http://es.inel.gov/techinfo/case/comm/3mcomp-d.html